"He telleth the number of the Stars, and calleth them all by their names."

THE

GEOGRAPHY OF THE HEAVENS,

AND

CLASS-BOOK OF ASTRONOMY:

ACCOMPANIED BY

A CELESTIAL ATLAS.

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GREATLY ENLARGED, REVISED AND ILLUSTRATED,

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PREFACE.

THE rapid progress of the science of astronomy, for the last few years, has again rendered it necessary to revise the *Geography of the Heavens*—a work, the popularity of which is sufficiently proved by a sale of 250,000 copies. The editor has, therefore, availed himself of the occasion to make such improvements, both in the book and maps, as seemed to be demanded by the progress of the science, and the most approved methods of instruction. Among these improvements we may mention the following :—

1. The *matter* of the book has been thoroughly assorted ; the most important paragraphs being printed in large type, and numbered, as in most modern text-books ; while that which seemed in the main explanatory of the more important portions, is left in small print. By this means an agreeable variety is afforded to the eye, while the book is made to contain far more matter, and is, consequently, far more complete, than it could otherwise have been.

2. A new set of Questions has been prepared throughout. These are brief, topical and suggestive ; and numbered to answer to the paragraphs to which they relate.

3. A complete list of *Telescopic Objects* in each constellation has been inserted ; giving the Right Ascension and Declination of each object ; with a brief description of it ; and easy landmarks and directions by which it may be found ; and references to telescopic views of the same in the new maps. The color and relative magnitude of the components of the double stars, are also given. These Telescopic Objects, compiled with great labor from *Smyth's Cycle of Celestial Objects*, will be found especially

valuable to all institutions having an equatorial telescope Indeed, they greatly enhance the value of the work for all classes of students.

4. Several small constellations that were delineated on the maps, but were not described in former editions of the book, have been described, and their history given in the present edition.

5. The *page* of the book has been greatly enlarged, for the double purpose of printing more matter and in larger type; and to afford scope for wood-cut illustrations. Of these, great numbers have been introduced into the second part of the work, adapting it, in this respect also, to the wants of both teacher and student.

6. Still further to illustrate the second part of the work, the first map of the atlas has been re-drawn and re-engraved, so as to illustrate *more* and *better* than the old map.

7. Two entirely *new maps* have been introduced into the Atlas, containing views of eighty different celestial objects; such as Double Stars, Clusters, Nebulæ, Comets, &c. These are all referred to in the book, and in turn refer from the objects back to the page of the book where they are described. These maps and the corresponding descriptions in the book will be found not only extremely interesting, but of incalculable value to the student.

8. A chapter on the history, structure and use of Telescopes, Transit Instruments, &c., has been introduced—a subject which every student of astronomy should understand, but one to which no attention was given in the previous editions.

Such are some of the principal new features of the present edition—larger type, new questions, telescopic objects, new maps, new matter, and numerous illustrations, making it the most perfect and complete text-book of astronomy ever offered to the American public.

H. Mattison

New York, April, 1856.

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INTRODUCTION

1. ASTRONOMY is the science of the heavenly bodies—the Sun, Moon, Planets, Comets, and Fixed Stars.

2. In entering upon this study, the phenomena of the heavens, as they appear on a clear evening, are the first objects that demand our attention. Our first step is to learn the names and positions of the heavenly bodies, so that we can identify, and distinguish them from each other.

In this manner they were observed and studied ages before books were written, and it was only after many careful and repeated observations, that systems and theories of Astronomy were formed. To the visible heavens, then, the attention of the pupil should be first directed, for it is only when he shall have become, in some measure, familiar with them, that he will be able to *locate* his Astronomical knowledge, or fully comprehend the terms of the science.

3. For the sake of convenient reference, the heavens were early divided into constellations, and particular names assigned to the constellations and to the stars which they contain. A constellation may be defined to be a cluster or group of stars embraced in the outline of some figure. These figures are, in many cases, creations of the imagination; but in others, the stars are in reality so arranged as to form figures which have some resemblance to the objects whose names have been assigned to them.

These divisions of the celestial sphere bear a striking analogy to the civil divisions of the globe. The constellations answer to states and kingdoms, the most brilliant clusters to towns and cities, and the number of stars in each, to their respective population. The pupil can trace the boundaries of any constellation, and name all its stars, one by one, as readily as he can trace the boundaries of a state, or name the towns and cities from a map of New England. In this sense, there may be truly said to be a Geography of the Heavens.

4. The stars are considered as forming, with reference to

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1. What is Astronomy? 2. What first studied? First step? 3. How are the heavens divided, and why? What is a constellation? What of these figures? In what sense may there really be a "*Geography of the heavens?*" 4. How are the stars classified, as respects their magnitudes? What expedient for designating their places in the heavens?

their magnitudes, sixteen classes; the brightest being called stars of the first magnitude, the next brightest, stars of the second magnitude, and so on to the sixth class, which consists of the smallest stars visible to the naked eye. The next ten classes are seen only through telescopes.

In order to be able to designate with precision their situations, imaginary circles have been considered as drawn in the heavens, most of which correspond to, and are in the same plane with, similar circles, supposed for similar purposes, to be drawn on the surface of the Earth.

5. In order to facilitate the study of Astronomy, artificial representations of the heavens, similar to those of the surface of the Earth, have been made. Thus, a Celestial Atlas, composed of several maps, accompanies this work. Before, however, proceeding to explain its use, it is necessary to make the pupil acquainted with the imaginary circles alluded to, called the *Circles of the Sphere.*

CIRCLES OF THE SPHERE.

6. The *Axis of the Earth* is an imaginary line, passing through its centre, north and south, about which its diurnal revolution is performed.

The *Poles of the Earth* are the extremities of its axis.

The *Axis of the Heavens* is the axis of the Earth produced both ways to the concave surface of the heavens.

The *Poles of the Heavens* are the extremities of their axis.

The *Equator of the Earth* is an imaginary great circle passing round the Earth, east and west, everywhere equally distant from the poles, and dividing it into northern and southern hemispheres.

The *Equator of the Heavens*, or *Equinoctial*, is the great circle formed on the concave surface of the heavens, by producing the plane of the Earth's equator.

A plane is that which has surface but not thickness. The plane of a circle is that imaginary superficies which is bounded by the circle.

7. The *Rational Horizon* is an imaginary great circle, whose plane, passing through the centre of the Earth, divides the heavens into two hemispheres, of which the upper one is called the

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5. What helps to facilitate the study of the heavens? Circles? Called what? 6. Axis of the Earth? Poles? Axis of the heavens? Poles of the heavens? Equator of the Earth? Equator of the heavens, or Equinoctial? 7. Rational horizon? Sensible or apparent?

visible hemisphere, and the lower one, the invisible hemisphere. It is the plane of this circle which determines the rising and setting of the heavenly bodies.

The *Sensible* or *Apparent Horizon*, is the circle which terminates our view, where the Earth and sky appear to meet.

To a person standing on a plain, this circle is but a few miles in diameter. If the eye be elevated five feet, the radius of the sensible horizon will be less than two miles and three quarters; if the eye be elevated six feet, it will be just three miles. The observer being always in the centre of the sensible horizon, it will move as he moves, and enlarge or contract, as his station is elevated or depressed.

8. The *Poles of the Horizon* are two points, of which the one is directly overhead, and is called the *Zenith;* the other is directly underfoot, and is called the *Nadir.*

Vertical Circles are circles drawn through the Zenith and Nadir of any place, cutting the horizon at right angles.

The *Prime Vertical* is that which passes through the east and west points of the horizon.

9. The *Ecliptic* is the plane of the Earth's orbit; or the great circle which the Sun appears to describe annually among the stars. It crosses the Equinoctial, a little obliquely, in two opposite points, which are called the *Equinoxes.* The Sun rises in one of these points on the 21st of March; this point is called the *Vernal* Equinox. It sets in the opposite point on the 23d of September; this point is called the *Autumnal* Equinox. One half of the Ecliptic lies on the north side of the Equinoctial, the other half on the south side, making an angle with it of $23\frac{1}{2}°$. This angle is called the *obliquity of the Ecliptic.* The axis of the Ecliptic makes the same angle with the axis of the heavens; so that the poles of each are $23\frac{1}{2}°$ apart.

This angle is perpetually decreasing. At the commencement of the Christian era, it was about 23° 45′. At the beginning of 1836, it was only 23° 27′ 38″, showing an annual diminution of about half a second, or 45″.70 in a hundred years. A time will arrive, however, when this angle, having reached its minimum, will again increase in the same ratio that it had before diminished, and thus it will continue to oscillate at long periods, between certain limits, which are said to be comprised within the space of 20° 42′.

10. The Ecliptic, like every other circle, contains 360°, and it is divided into 12 equal arcs of 30° each, called signs, which the ancients distinguished by particular names. This division commences at the vernal equinox, and is continued eastwardly round to the same point again in the following order: *Aries*, *Taurus*, *Gemini*, *Cancer*, *Leo*, *Virgo*, *Libra*, *Scorpio*, *Sagittarius*, *Capri-*

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8. Poles of the horizon? Vertical circles? Prime Vertical? 9. Ecliptic? Equinoxes? How is the Ecliptic situated with respect to the Equinoctial? Obliquity of Ecliptic? Is this angle permanent? 10. How is the Ecliptic divided? Where commenced, and how reckoned? Name signs in order? How does the Sun proceed through the signs?

cornus, Aquarius, Pisces. The Sun, commencing at the first degree of Aries, about the 21st of March, passes, at a mean rate, through one sign every month.

11. The *Zodiac* is a zone or girdle, about 16 degrees in breadth, extending quite round the heavens, and including all the heavenly bodies within 8° on each side of the ecliptic. It includes, also, the orbits of all the planets, except some of the asteroids, since they are never seen beyond 8° either north or south of the ecliptic.

12. *Parallels of Latitude* are small circles imagined to be drawn on the Earth's surface, north and south of the equator, and parallel to it.

Parallels of Declination are small circles, imagined to be drawn on the concave surface of the heavens, north and south of the equinoctial, and parallel to it; or they may be considered as circles formed by producing the parallels of latitude to the heavens.

13. The *Tropic of Cancer* is a small circle, which lies 23½° north of the Equinoctial, and parallel to it. The *Tropic of Capricorn* is a small circle, which lies 23½° south of the Equinoctial, and parallel to it. On the *celestial* sphere, these two circles mark the limits of the Sun's farthest declination, north and south. On the *terrestrial* sphere, they divide the torrid from the two temperate zones. That point in the ecliptic which touches the tropic of Cancer, is called the *Summer Solstice;* and that point in the ecliptic which touches the tropic of Capricorn, is called the *Winter Solstice.*

The distance of these two points from the equinoctial, is always equal to the obliquity of the ecliptic, which, in round numbers, is 23c°; but, as we have seen, the obliquity of the ecliptic is continually changing; therefore the position of the tropics must make a correspondent change.

14. The *Colures* are two great circles which pass through the poles of the heavens, dividing the ecliptic into four equal parts, and mark the seasons of the year. One of them passes through the equinoxes at Aries and Libra, and is thence called the *Equinoctial Colure;* the other passes through the solstitial points or the points of the Sun's greatest declination north and south, and is thence called the *Solstitial Colure.*

The Sun is in the equinoctial points the 21st of March and the 23d of September. He is in the solstitial points the 22d of June and the 22d of December.

15. The *Polar Circles* are two small circles, each about 66½°

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11. What is the Zodiac? 12. Parallels of latitude? Of declination? 13. The tropics? Cancer? Capricorn? What do these circles mark in the celestial sphere? On the terrestrial? 14. The Colures? Where situated? When is the Sun at the equinoctial points? The solsticial? 15. What are the Polar Circles?

from the equator, being always at the same distance from the poles that the tropics are from the equator. The northern is called the *Arctic* circle, and the southern the *Antarctic* circle.

16. *Meridians* are imaginary great circles drawn through the poles of the world, cutting the equator and the equinoctial at right angles.

Every place on the Earth, and every corresponding point in the heavens, is considered as having a meridian passing through it; although astronomers apply but 24 to the heavens, thus dividing the whole concave surface into 24 sections, each 15° in width. These meridians mark the space which the heavenly bodies appear to describe, every hour, for the 24 hours of the day. They are thence sometimes denominated *Hour Circles.*

In measuring distances and determining positions on the Earth, the equator and some fixed meridian, as that of Greenwich, contain the primary starting points; in the heavens these points are in the ecliptic, the equinoctial, and that great meridian which passes through the first point of Aries, called the equinoctial colure.

17. *Latitude on the Earth,* is distance north or south of the *equator*, and is measured on the meridian.

Latitude in the Heavens, is distance north or south of the *ecliptic,* and at right angles with it.

Longitude on the Earth, is distance either east or west from some fixed meridian, measured on the *equator.*

Longitude in the Heavens, is distance east from the first point of Aries, measured on the *ecliptic.*

18. *Declination* is the distance of a heavenly body either north or south of the equinoctial, measured on a meridian.

Right Ascension is the distance of a heavenly body east from the first point of Aries, measured on the equinoctial.

It is more convenient to describe the situation of the heavenly bodies by their declination and right ascension, than by their latitude and longitude, since the former corresponds to terrestrial latitude and longitude.

Latitude and declination may extend 90° and no more. Terrestrial longitude may extend 180° either east or west; but celestial longitude and right ascension, being reckoned in only one direction, extend entirely round the circle, or 360°.

It is easy to convert right ascension into time, or time into right ascension, for if a heavenly body is one hour in passing over 15°, it will be one fifteenth of an hour, or four minutes, in passing over 1°.

If the first point of Aries be on the meridian at 12 o'clock, the next hour line, which is 15° E. of it, will come to the meridian at 1 o'clock; the second hour line at 2 o'clock; the third at 3, &c. Of any two bodies whose right ascensions are given, that one will pass the meridian *first* which has the *least* right ascension.

19. In consequence of the Earth's motion eastward in its orbit, the stars seem to have a motion westward, besides their apparent diurnal motion caused by the Earth's revolution on its axis; so that they rise and set sooner every succeeding day by about four minutes, than they did on the preceding. This is

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16. Meridians? How many? What other name? How measure distances on the earth? In the heavens? 17. What is latitude on the earth? In the heavens? Longitude on the earth? In the heavens? 18. Declination? Right ascension Why describe by D. and R. A.? Extent of latitude? Declination? Longitude and R. A? How convert R. A. into time? Which of two bodies given will first pass the meridian? 19. What apparent motion of stars? Cause? Results?

called their daily acceleration. It amounts to just *two hours* a month. On this account we have not always the same constellations visible to us throughout the year. While some, that were not visible before, are successively rising to view in the east, and ascending to the meridian, others sink beneath the western horizon, and are seen no more, until, having passed through the lower hemisphere, they again reappear in the east.

DESCRIPTION AND USE OF THE MAPS.

20. The first map of the atlas represents, upon a large scale, a general view of the solar system. This will be more fully described in the second part of the work.

The next six maps represent different sections of the concave surface of the heavens. The first of these exhibits the principal constellations visible to us in October, November, and December; the second, those visible in January, February, and March; the third, those visible in April, May, and June; and the fourth, those visible in July, August, and September; with the exception, however, of the constellations which lie beyond the 50th degree of north and south declination, of which, indeed, those around the North Pole are *always*, and those around the South Pole, *never* visible to us.

21. These constellations are represented on the sixth and seventh maps, called circumpolar maps, which are an exact continuation of the others, and if joined to them at their corresponding degrees of right ascension and declination, they might be considered as constituting one map. The scale on which all the above-mentioned maps are drawn is that of a 16-inch globe. The lines drawn on the maps have been already defined; and their use, being nearly the same with those in geography, will be readily understood. Those which are drawn from right to left, on each side of the equinoctial and parallel to it, are called *Parallels of Declination.* Those which are drawn up and down through the maps, at intervals of 15°, are called *Meridians of Right Ascension*, or *Hour Circles*.

The scale at the top and bottom of the first four maps, and in the circumference of the circumpolar maps, indicates the daily progress of the stars in right ascension, and shows on what day of the month any star will be on the meridian at 9 o'clock in the evening.

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20. What said of maps? First? Next six? 21. Sixth and seventh? Scale? Describe lines? Scale indicates what?

22. The first four maps of the heavens are so constructed that the pupil in using them must suppose himself to face the south, and to hold them directly overhead in such manner that the top of the map shall be towards the north, and the bottom towards the south; the right hand side of the map will then be west, and the left-hand east. In using the circumpolar maps he must suppose himself to face the pole, and to hold them in such a manner that the day of the given month shall be uppermost.

The constellation called the Great Bear is an exception to this rule; in this constellation the principal stars are marked in the order of their right ascension.

That point of projection for the maps which would exhibit each successive portion of the heavens directly overhead at 9 o'clock in the evening, was chosen, because in summer at an earlier hour the twilight would bedim our observation of the stars, and at other seasons of the year it is easier to look up to stars that want an hour of their meridian altitude than to those which are directly overhead.

CLASSIFICATION OF STARS, NEBULÆ, &c.

23. For purposes of convenience in finding or referring to particular stars, recourse is had to a variety of artificial methods of classification. First, the whole concave of the heavens is divided into sections or groups of stars, of greater or less extent, called *Constellations*.—(Of the origin of these figures see page 143). Next, they are classified according to their *magnitudes*, (as already stated art. 4), and designated on the maps accordingly. Thirdly, the stars of *each constellation* are classified according to their magnitudes *in relation to each other*, and without reference to other constellations. Thus, for instance, the largest star in Taurus is marked α, *Alpha*; the next largest β, *Beta;* the next, γ, *Gamma*, &c., till the Greek alphabet is exhausted. Then the Roman (or English) is taken up, and finally, if necessary, recourse is had to figures.

This useful method of designating particular stars by the use of the Greek and Roman alphabet, was invented by John Bayer, of Augsburg, in Germany, in 1603. It has been adopted by all succeeding astronomers, and extended by the addition of the Arabic notation 1, 2, 3, &c., wherever the stars in a constellation outnumber both alphabets.

As Greek letters so frequently occur in catalogues and maps of the stars and on the celestial globes, the Greek alphabet is here introduced for the use of those who are unacquainted with it. The capitals are seldom used for designating the stars, but are here given for the sake of regularity.

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22. How use the first four maps of the heavens? Circumpolar? What exception? What point of projection chosen, and why? 23. Classification or designation of stars? By whom invented, and when?

THE GREEK ALPHABET.

Α	α	Alpha	Ν	ν	Nu
Β	β	Beta	Ξ	ξ	Xi
Γ	γ	Gamma	Ο	ο	Omicron
Δ	δ	Delta	Π	π	Pi
Ε	ε	Epsilon	Ρ	ρ	Rho
Ζ	ζ	Zeta	Σ	ς	Sigma
Η	η	Eta	Τ	τ	Tau
Θ	θ	Theta	Υ	υ	Upsilon
Ι	ι	Iota	Φ	φ	Phi
Κ	κ	Kappa	Χ	χ	Chi
Λ	λ	Lambda	Ψ	ψ	Psi
Μ	μ	Mu	Ω	ω	Omega

24. As a further aid in finding particular stars, and especially in determining their number, and detecting changes, should any occur, *catalogues of the stars* have been constructed, one of which is over two thousand years old. Several of the principal stars have specific names, like the planets, as *Sirius, Aldebaran, Regulus*, &c.

25. The stars are still further distinguished, as *single, double, triple, multiple, binary, variable, new*, and *nebulous.*

A *single star* is one that appears as a unit under the most powerful telescopes. *Double, triple*, and *multiple stars*, are those that appear single to the naked eye, but by the aid of telescopes are found to consist of two or more stars. *Binary stars* are double stars revolving around each other, often called *Binary Systems. Variable stars* are those that are found to undergo certain fluctuations in their brightness, sometimes becoming quite invisible. In most cases these changes are periodical and regular, on which account they are called *Periodical stars. New stars* are those that suddenly blaze forth in some portion of the heavens previously void. *Nebulous stars* are those which are surrounded by a faint nebula, or halo of light or mist.

26. A *cluster* of stars is an assemblage or group, thrown promiscuously together, like the *Pleiades* and *Hyades* in Taurus, and the *Bee Hive* in Cancer. A *Nebula* is a cluster so remote as to appear only like a faint cloud or haze of light. *Resolvable Nebulæ*, are those that can be resolved into distinct stars by the aid of a telescope. *Irresolvable Nebulæ* are those that have not

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24. What further aid? Age? Names of stars? 25. Stars, how further distinguished? Single stars? Double, &c.? Binary? What other name? Variable stars? What other name and why? New stars? Nebulous? 26. What are clusters? Nebulæ? Resolvable Nebulæ? Irresolvable? Annular? Planetary?

as yet been thus resolved. *Annular Nebulæ* are those that have the form of an annulus or ring. *Planetary Nebulæ* are those that resemble planets in form, and in the sharpness of their outline. *Stellar Nebulæ* are those with a *star* in the centre, the same as nebulous stars, already described (25).

A more detailed account of the double stars, clusters and nebulæ, will be given after the student has become somewhat familiar with the constellations.

27. We may now imagine the pupil ready to begin the study of the visible heavens. The first thing of importance is to fix upon the proper starting point. This, on many accounts, would seem to be the North Polar Star. Its position is apparently the same every hour of the night throughout the year, while the other stars are continually moving. Many of the stars also in that region of the skies never set, so that when the sky is clear, they may be seen at any hour of the night. They revolve about the pole in small circles, and never disappear below the horizon.

On this account they are said to be within the circle of perpetual apparition. On the other hand, the identity of the North Polar Star, strange as it may appear, is not so easily determined by those who are just entering upon this study, as that of some others. For this reason, the point *directly overhead*, called the zenith, is preferable, since upon this point every one can fix with certainty in whatever latitude he may be. It will be alike to all the central point of the visible heavens, and to it the pupil will learn imperceptibly to refer the bearing, motion, and distances of the heavenly bodies.

That meridional point in each map, whose declination corresponds with the latitude of the place of observation, represents the zenith of the heavens at that place; and those constellations of stars which occupy this position on the maps, will be seen directly overhead at 9 o'clock in the evening of the day through which the meridian passes. Thus in Georgia, for instance, the starting point should be those stars which are situated in this meridian near the 33d degree of north declination, while in New England it should be those which are situated in it near the 42d degree.

28. We *might*, however, begin with the stars near either of the meridians represented on the maps, the only rule of selection being to commence at that which approaches nearest to being overhead at the *time required*. We have chosen for our starting point in this work that meridian which passes through the vernal equinox at the first point of Aries, not only because it is the meridian from which the distances of all the heavenly bodies are measured; but especially because the student will thus be enabled to observe and compare the progressive motion of the constellations according to the order in which they are always arranged in catalogues, and also to mark the constellations of the Zodiac passing overhead as they rise one after another in their order, and to trace among them the orbits of the Earth and of the other planets.

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27. What first important in commencing study of the heavens? What star would seem best starting point? Why? Why *not* the best? What point preferable, and why? Illustration from map. 28. With what stars might we begin? What meridian chosen by the author? Why?

PART I.

THE CONSTELLATIONS

CHAPTER I.

CONSTELLATIONS ON THE MERIDIAN IN NOVEMBER.

ANDROMEDA.—MAP II.*

29. If we look directly overhead at 10 o'clock, on the 10th of November, we shall see the constellation celebrated in fable by the name of Andromeda. It is represented on the map by the figure of a woman having her arms extended, and chained by her wrists to a rock. It is bounded N. by Cassiopeia, E. by Perseus and the head of Medusa, and S. by the Triangles and the Northern Fish. It is situated between 20° and 50° of N. declination. Its mean right ascension is nearly 15°; or one hour E. of the equinoctial colure.

30. It consists of 66 visible stars, of which three are of the 2d magnitude, and two of the 3d; most of the rest are small. The stars directly in the zenith are too small to be seen in the presence of the moon, but the bright star Almaack (γ), of the 2d magnitude, in the left foot, may be seen 13° due E., and Merach (β), of the same magnitude, in the girdle 7° south of the zenith. This star is then nearly on the meridian, and with two others N.W. of it forms the girdle.

The three stars forming the girdle are of the 2d, 3d, and 4th magnitude, situated in a row, 3° and 4° apart, and are called Merach, Mu, and Nu.

31. If a straight line, connecting Almaack with Merach, be

* As the eastward motion of the earth in her orbit causes the sun to pass eastward annually around the heavens, and the constellations to rise earlier and earlier (19), the student will find it necessary to proceed *eastward* around the heavens, in studying the constellations. And as the right hand of the map is west, and the left hand east, we begin with the equinoctial colure, map II., and proceed to the *left* in the order in which the constellations successively arise.

29. What constellation? Maps, and why? (Note.) How Andromeda represented? Boundaries? Situation? Right ascension and declination? 30. Number of stars Magnitude? Almaack? Merach? "Girdle?" 31. Situation of Delta? Magnitude How otherwise known? Alpheratz? Substance of note (fine print)?

produced south-westerly, 8° farther, it will reach to (δ) *Delta*, a star of the 3d magnitude in the left breast. This star may be otherwise known by its forming a line, N. and S., with two smaller ones on either side of it ; or, by its constituting, with two others, a very small triangle, S. of it.

Nearly in a line with Almaack, Merach and Delta, but curving a little to the N. 7° farther, is a lone star of the 2d magnitude, in the head, called Alpheratz (*a*). This is the N.E. corner of the great "Square of Pegasus," to be hereafter described.

It will be well to have the position of Alpheratz well fixed in the mind, because it is but one minute west of the great equinoctial colure, or first meridian of the heavens, and forms nearly a right line with Algenib, in the wing of Pegasus, 14° S. of it, and with Beta in Cassiopeia, 30° N. of it. If a line, connecting these three stars, be produced, it will terminate in the pole. These three guides, in connection with the North Polar Star, point out to astronomers the position of that great circle in the heavens from which the right ascension of all the heavenly bodies is measured.

MYTHOLOGICAL HISTORY.

32. The story of Andromeda, from which this constellation derives its name, is as follows: She was daughter of Cepheus, King of Ethiopia, by Cassiopeia. She was promised in marriage to Phineus, her uncle, when Neptune drowned the kingdom, and sent a sea monster to ravage the country, to appease the resentment which his favorite nymphs bore against Cassiopeia, because she had boasted herself fairer than Juno and the Nereides. The oracle of Jupiter Ammon was consulted, and nothing could pacify the anger of Neptune unless the beautiful Andromeda should be exposed to the sea monster. She was accordingly chained to a rock for this purpose, near Joppa (now Jaffa, in Syria), and at the moment the monster was going to devour her, Perseus, who was then returning through the air from the conquest of the Gorgons, saw her, and was captivated by her beauty.

"Chained to a rock she stood ; young Perseus stay'd
His rapid flight, to woo the beauteous maid."

He promised to deliver her and destroy the monster if Cepheus would give her to him in marriage. Cepheus consented, and Perseus instantly changed the sea monster into a rock, by showing him Medusa's head, which was still reeking in his hand. The enraged Phineus opposed their nuptials, and a violent battle ensued, in which he, also, was turned into a stone, by the petrifying influence of the Gorgon's head.

The morals, maxims, and historical events of the ancients, were usually communicated in fable or allegory. The fable of Andromeda and the sea monster might mean that she was courted by some monster of a sea-captain, who attempted to carry her away, but was prevented by another more gallant and successful rival.

TELESCOPIC OBJECTS.

33. Under the head of Telescopic Objects, will be included clusters and nebulæ that are visible to the naked eye, as well as the principal objects of interest that are strictly telescopic. In describing the location of these objects, R. A. will denote *Right Ascension;* and Dec., *Declination.* The initials N. and S. will indicate whether the declination is *North* or *South* of the equinoctial.

In describing the location of the telescopic object, the R. A. will be given in *time;* viz., in *hours*, *minutes*, and *seconds*, instead of degrees, minutes, and seconds; each hour answering to 15°. The hour circles are distinctly drawn on all the maps, the first being 15° east of the equinoctial colure (Map II.), and so on eastward to the same point again. The hours will be seen marked just under the equinoctial, which is marked off into degrees, each of which answers to four minutes of time. The student will soon find it much more convenient to reckon R. A. by *hours*, on the maps, than by degrees, &c.

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32. HISTORY.—What may it have meant?

33. What included among Telescopic Objects? What meant by R. A.? Dec.? N. and S.? How R. A. laid down? How on map? What mode of describing components of double stars? Of *a* Andromeda? Of discrepancies between R. A. given, and location of stars on the maps? How is R. A. given in locating objects? Why? How are hours marked on the maps? The minutes?

34. In consequence of the perpetual *recession* of the equinoxes westward, the R. A. of objects is constantly increased by about 50″ per year. It is vain, therefore, to attempt to give R. A. for the *time when a book will be used;* or to construct maps that will show objects in their true place, for different years to come. The necessary allowance must be made in all cases; so that the R. A. for one epoch is about as good as another. The R. A. here given is from *Smyth's Celestial Cycle*, epoch Jan. 1, 1840. Maps should be re-engraved every fifty years, but for all shorter periods allowance can be made by the student. As the maps accompanying this work were drawn and engraved in 1835, their present R. A. (1854) is about 17′ or 4m. of time *east* of their places on the maps.

35. The *order* in which the telescopic objects will be arranged is first the double stars; secondly, clusters; and lastly the nebulæ. The double stars will be classed according to their order in the respective constellations; i.e., α first, β next, &c. Thus, as the largest objects are first named, the student can begin with those easiest found, and requiring the least telescopic power; and proceed from the easier to those more difficult. The same plan is generally pursued with the clusters and nebulæ.

TELESCOPIC OBJECTS IN ANDROMEDA.

1. α ANDROMEDÆ (Alpheratz)—A star with a minute companion, R. A. 0h. 0m. 08s.; Dec., N. 28° 12′ 05″. A. 1, bright white; B. 11, purplish. On the map it is *west* of the equinoctial, the map having been engraved some twenty years; but the equinox having constantly receded westward, had passed Alpheratz before 1840, some 8′. Similar discrepancies between the R. A. given and the location of different stars on the map, are due to the same cause.

2. β ANDROMEDÆ (Merach)—A bright star with a distant telescopic companion, R. A. 1h. 00m. 47s.; Dec., N. 34° 46′ 08″. A. 2, fine yellow; B. 12, pale blue, with several small stars in the field.

3. γ ANDROMEDÆ (*Almaack*)—A SPLENDID DOUBLE STAR on the right foot, R. A. 1h. 54m. 36s; Dec. N. 41° 33′ 06″. A. 3½, orange color; B. 5½, emerald green. Found by a line from δ to β, and about twice as far beyond. (Map VIII., Fig. 1.)

4. δ ANDROMEDÆ—A bright star on the right breast, with a distant telescopic companion, R. A. 0h. 30m. 47s.; Dec., N. 29° 59′ 01″. A. 3, orange; B. 11½, dusky; with the small stars in the southern part of the field.

5. κ ANDROMEDÆ—A wide, but delicate TRIPLE STAR, in the northern hand; midway between β Pegasi and α Cassiopeia; or about 18° from each; R. A. 23h. 32m. 33s; Dec., N. 43° 27′ 0″. A. 5, brilliant white; B. 14, dusky; C. 12, ash-colored.

6. AN ELONGATED NEBULA on the lady's right foot, R. A, 2h. 12m. 35s.; Dec., N. 41° 36″. It was discovered by Miss Caroline Herschell, in 1783. Sir William Herschell described it as having "a black division or chink in the middle." He regarded it as a flat ring of enormous dimensions, seen very obliquely. Captain Smyth says: "In my telescope it is certainly brighter at the edges than along the central part." See map VIII., Fig. 21.

7. About 2° from Nu at the north-western extremity of the girdle, R. A. 00° 34m. 05s., N. Dec., 40° 23′ 06″, is a remarkable nebula of very minute stars, and the only one of the kind which is ever visible to the naked eye. It resembles two cones of light, joined at their base, about ⅔° in length, and ¼° in breadth. It was known as far back as A.D. 905, is of an oval shape, and is described by Smyth as "an overpowering nebula, with a companion about 25′ in the south vertical." Sir William Herschell considered this the nearest of all the great nebulæ, and yet so remote that it would require 6,000 years for *light* to pass from it to our system, though flying at the rate of 190,000 miles per second! Fig. 22, map VIII., is a representation of this object.

PISCES (THE FISHES).—MAP V.

36. This constellation is now the first in order of the twelve constellations of the Zodiac, and is usually represented by two fishes tied a considerable distance apart, at the extremities of a long undulating cord, or ribbon. It occupies a large triangular space

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34. What said of the change of R. A. of objects? Cause? Epoch of R. A. given in book? Of that marked on maps? Allowance to be made in finding objects by maps? 35. Order in which objects are presented? Advantage of this arrangement?

TELESCOPIC OBJECTS.—What double stars? α? β? γ? What clusters or nebulæ? Shown on map, or not?

36. Pisces? Where situated? What now called?

in the heavens, and its outline at first is somewhat difficult to be traced.

In consequence of the annual precession of the stars, the *constellation* Pisces has now come to occupy the *sign* Aries; each constellation having advanced one whole sign in the order of the Zodiac. The Sun enters the sign Pisces, while the Earth enters that of Virgo, about the 19th of February, but he does not reach the *constellation* Pisces before the 6th of March. The Fishes, therefore, are now called the "Leaders of the Celestial Hosts."—*See Aries.*

37. That loose assemblage of small stars directly south of Merach, in the constellation of Andromeda, constitutes the *Northern Fish,* whose mean length is about 16°, and breadth, 7°. Its mean right ascension is 15°, and its declination 25° N. Consequently, it is on the meridian the 24th of November; and from its breadth, is more than a week in passing over it.

38. The Northern Fish and its ribbon, beginning at Merach, may by a train of small stars, be traced in a S. S. easterly direction, for a distance of 33°, until we come to the star El Rischa, of the 3d magnitude, which is situated in the node, or *flexure* of the ribbon. This is the principal star in the constellation, and is situated 2° N. of the equinoctial, and 53 minutes east of the meridian.

Seven degrees S. E. of El Rischa, passing by three or four very small stars, we come to Mira, in the whale, a star of about the 3d magnitude, and known as the "Wonderful Star of 1596." El Rischa may be otherwise identified by means of a remarkable cluster of five stars in the form of a *pentagon,* about 15° E. of it.—*See Cetus.*

39. From El Rischa the ribbon or cord makes a sudden flexure, doubling back across the ecliptic, where we meet with three stars of the fourth magnitude situated in a row 3 and 4° apart, marked on the map Zeta, Epsilon, Delta. From Delta the ribbon runs north and westerly along the Zodiac, and terminates at Beta, a star of the 4th magnitude, 11° S. of Markab in Pegasus.

This part of the ribbon, including the Western Fish at the end of it, has a mean declination of 5° N., and may be seen throughout the month of November, passing the meridian slowly to the W., near where the sun passes it on the 1st of April.

40. Twelve degrees W. of this Fish, there are four small stars situated in the form of the letter Y. The two Fishes, and the cord between them, make two sides of a large triangle, 30° and 40° in length, the open part of which is towards the N. W. When the Northern Fish is on the meridian, the Western is nearly two hours past it. This constellation is bounded N. by

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37. Northern Fish? Length? Dec.? When on the meridian? 38. How trace the Northern Fish? To what star? Magnitude? Where situated? 39. From El Rischa? From Delta? Mean declination of this part of the ribbon? 40. What 12° west of this fish? What do the two fishes, &c., make? Boundaries of Pisces?

Andromeda, W. by Andromeda and Pegasus, S. by the Cascade, and E. by the Whale, the Ram and the Triangles.

When, to enable the pupil to find any star, its direction from another is given, the latter is always understood to be on the meridian.

After a little experience with the maps, even though unaccompanied by directions, the ingenious youth will be able, of himself, to devise a great many expedients and facilities for tracing the constellations, or selecting out particular stars.

In using a circumpolar map, face the pole, and hold it up in your hands in such a manner that the part which contains the name of the given month shall be uppermost, and you will have a portraiture of the heavens as seen at that time.

The constellations about the Antarctic Pole are not visible in the United States; those about the Arctic or Northern Pole, are always visible.

HISTORY.

41. The ancient Greeks, who have some fable to account for the origin of almost every constellation, say, that as Venus and her son Cupid were one day on the banks of the Euphrates, they were greatly alarmed at the appearance of a terrible giant, named Typhon. Throwing themselves into the river, they were changed into fishes, and by this means escaped danger. To commemorate this event, Minerva placed two fishes among the stars.

According to Ovid, Homer, and Virgil, this Typhon was a famous giant. He had a hundred heads, like those of a serpent or dragon. Flames of devouring fire darted from his mouth and eyes. He was no sooner born, than he made war against heaven, and so frightened the gods, that they fled and assumed different shapes. Jupiter became a ram: Mercury, an Ibis; Apollo, a crow; Juno, a cow; Bacchus, a goat; Diana, a cat; Venus, a fish, &c. The father of the gods, at last, put Typhon to flight, and crushed him under Mount Ætna.

The sentiment implied in the fable of this hideous monster, is evidently this: that there is in the world a description of men whose mouth is so "full of cursing and bitterness," derison and violence, that modest virtue is sometimes forced to disguise itself, or flee from their presence.

In the Hebrew Zodiac, Pisces is allotted to the escutcheon of Simeon.

No sign appears to have been considered of more malignant influence than *Pisces.* The astrological calendar describes the emblems of this constellation as indicative of violence and death. Both the Syrians and Egyptians abstained from eating fish, out of dread and abhorrence; and when the latter would represent anything as odious, or express hatred by hieroglyphics, they painted a *fish.*

TELESCOPIC OBJECTS.

1. α Piscium (*El Rischa*)—A close double star in the eastern extremity of the ribbon, R. A. 1h. 53m. 46s.; Dec. N. 1° 59′ 03″. A. 5, pale green; B. 6, blue; a splendid object, and easily found.

2. ξ Piscium—A neat double star in the ribbon, about 13° north-west of α, R. A. 1h. 5m. 21s.; Dec. N. 6° 43′ 07″. A. 6, silvery white; B. 8, pale gray; a fine object.

3. ϕ Piscium—A close double star in the space between the two fishes, about half-way between η Andromeda and θ Ceti; R. A. 1h. 2m. 31s.; Dec. N. 8° 42′. A. 8, white; B. 14, pale blue.

4. A neat double star, about 4° south of *Algenib*, in the wing of Pegasus, R. A. 0h. 1m. 53s.; Dec. N. 10° 14′ 06″. A. 6, silvery white; B. 13½, pale blue.

5. A faint nebula in the eye of the western Fish, about 10° south-half-east of Markab, near γ Piscium; R. A. 23h. 06m. 36s.; Dec. 3° 39′ 7″: a very difficult object.

CASSIOPEIA.—MAP VI.

42. Cassiopeia is represented on the celestial map in regal state, seated on a throne or chair, holding in her left hand the branch

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41. History?—Greek account? Ovid's and others? Sentiment or moral? Hebrew Zodiac? Astrology?

Telescopic Objects.—Double stars? Clusters? Nebulæ? Shown on map, or not?

42. Cassiopeia? How represented? Head?

of a palm tree. Her head and body are seen in the Milky Way. Her foot rests upon the Arctic Circle, upon which her chair is placed. She is surrounded by the chief personages of her royal family. The king, her husband, is on her right hand—Perseus, her son-in-law, on her left—and Andromeda, her daughter, just above her.

43. This constellation is situated 26° N. of Andromeda, and midway between it and the North Polar Star. It may be seen from our latitude, at all hours of the night, and may be traced out at almost any season of the year. Its mean declination is 60° N. and its right ascension 12°. It is on our meridian the 22d of November, but does not sensibly change its position for several days; for it should be remembered that the apparent motion of the stars becomes slower and slower, as they approximate the poles.

44. Cassiopeia is a beautiful constellation, containing 55 stars that are visible to the naked eye; of which four are of the 3d magnitude, and so situated as to form, with one or two smaller ones, the figure of an inverted chair.

> ——————"Wide her stars
> Dispersed, nor shine with mutual aid improved;
> Nor dazzle, brilliant with contiguous flame:
> Their number fifty-five."

45. *Caph*, in the garland of the chair, is almost exactly in the equinoctial colure, 30° N. of Alpheratz, with which, and the Polar Star, it forms a straight line. Caph is therefore on the meridian the 10th of November, and one hour past it on the 24th. It is the westernmost star of the bright cluster. *Shedir*, in the breast, is the uppermost star of the five bright ones, and is 5° S. E. of Caph: the other three bright ones, forming the chair, are easily distinguished, as they meet the eye at the first glance.

There is an importance attached to the position of Caph that concerns the mariner and the surveyor. It is used, in connection with observations on the Polar Star, for determining the latitude of places, and for discovering the magnetic variation of the needle.

46. It is generally supposed that the North Polar Star, so called, is the real immovable pole of the heavens; but this is a mistake. It is *so near* the true pole that it has obtained the

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43. Situation? How seen? R. A. and Dec.? When on meridian? 44. Number of stars? Magnitudes? Figure? Character of this constellation? 45. Caph? How situated? When on meridian? Shedir? Importance attached to Caph? 46. Pole star? Is it the true pole? What variation? How pole star situated with reference to

appellation of the *North Polar Star;* but it is, in reality, more than a *degree and a half* distant from it, and revolves about the true pole every 24 hours, in a circle whose radius is 1° 31′. It will consequently, in 24 hours, be twice on the meridian, once *above*, and once *below* the pole; and twice at its greatest elongation E. and W.

The Polar Star not being exactly in the N. pole of the heavens, but *one degree and 31 minutes* on that side of it which is towards Caph, the position of the latter becomes important, as it always shows on which side of the *true* pole the polar star is.

There is another important fact in relation to the position of this star. It is *equidistant* from the pole, and exactly *opposite* another remarkable star in the *square* of the Great Bear, on the other side of the pole. [*See Megrez.*] It also serves to mark a spot in the starry heavens, rendered memorable as being the place of a lost star. Two hundred and fifty years ago, a bright star shone 5° N. N. E. of Caph, where now is a dark void!

On the 8th of November, 1572, Tycho Brahe and Cornelius Gemma saw a star in the constellation of Cassiopeia, which became, all at once, so brilliant, that it surpassed the splendor of the brightest planets, and might be seen even at noonday. Gradually, this great brilliancy diminished, until the 15th of March, 1573, when, without moving from its place, it became utterly extinct.

Its color, during this time, exhibited all the phenomena of a prodigious flame—first, it was of a dazzling white, then of a reddish yellow, and lastly of an ashy paleness, in which its light expired. It is impossible, says Mrs. Somerville, to imagine anything more tremendous than a conflagration that could be visible at such a distance. It was seen for sixteen months. Some astronomers imagined that it would reappear again after 150 years; but it has never been discovered since. This phenomenon alarmed all the astronomers of the age, who beheld it; and many of them wrote dissertations concerning it.

Rev. Professor Vince, one of the most learned and pious astronomers of the age, has this remark:—" The disappearance of some stars may be the destruction of that system at the time appointed by the Deity for the probation of its inhabitants; and the appearance of new stars may be the formation of new systems for new races of beings then called into existence to adore the works of their Creator."

Thus, we may conceive the Deity to have been employed from all eternity, and thus he may continue to be employed for endless ages; forming new systems of beings to adore him; and transplanting beings already formed into happier regions, who will continue to rise higher and higher in their enjoyments, and go on to contemplate system after system through the boundless universe.

La Place says:—As to those stars which suddenly shine forth with a very vivid light, and then immediately disappear, it is extremely probable that great conflagrations, produced by extraordinary causes, take place on their surface. This conjecture, continues he, is confirmed by their change of color, which is analogous to that presented to us on the earth by those bodies which are set on fire, and then gradually extinguished.

The late eminent Dr. Good also observes that—Worlds, and systems of worlds, are not only perpetually creating, but also perpetually disappearing. It is an extraordinary fact, that within the period of the last century, not less than thirteen stars, in different constellations, seem to have totally perished, and ten new ones to have been created. In many instances it is unquestionable, that the stars themselves, the supposed habitation of other kinds or orders of intelligent beings, together with the different planets by which it is probable they were surrounded, have utterly vanished, and the spots which they occupied in the heavens have become blanks! What has befallen other systems will assuredly befall our own. Of the time and the manner we know nothing, but the fact is incontrovertible; it is foretold by revelation; it is inscribed in the heavens; it is felt through the earth. Such is the awful and daily text; what then ought to be the comment?

The great and good Beza, falling in with the superstition of his age, attempted to prove that this was a comet, or the same luminous appearance which conducted the magi, or wise men of the East, into Palestine, at the birth of our Saviour, and that it now appeared to announce his second coming.

Caph? What other important fact in relation to the position of Caph? What remarkable fact stated? By whom attested? Describe phenomenon? Mrs. Somerville's remark? Other astronomers'? Professor Vince's remarks? The author's? La Place's? Dr. Good's? Beza's?

HISTORY.

Cassiopeia was the wife of Cepheus, King of Ethiopia, and mother of Andromeda. She was a queen of matchless beauty, and seemed to be sensible of it; for she even boasted herself fairer than Juno, the sister of Jupiter, or the Nereides—a name given to the sea-nymphs. This so provoked the ladies of the sea, that they complained to Neptune of the insult, who sent a frightful monster to ravage her coast, as a punishment for her insolence. But the anger of Neptune and the jealousy of the nymphs were not thus appeased. They demanded, and it was finally ordained that Cassiopeia should chain her daughter Andromeda, whom she tenderly loved, to a desert rock on the beach, and leave her exposed to the fury of this monster. She was thus left, and the monster approached, but just as he was going to devour her, Perseus killed him.

"The saviour youth the royal pair confess.
And with heav'd hands, their daughter's bridegroom bless."
Eusden's Ovid.

TELESCOPIC OBJECTS.

1. α CASSIOPEÆ (*Shedir*)—A bright star, with a companion in the bosom of the figure; R. A. 0h. 31m. 29s.; Dec. 65° 39′ 05″. A 3, pale rose tint; B 10½, small blue. Smyth and Herschell note Shedir as variable.

2. β CASSIOPEÆ (*Caph*)—A bright star on the left side, with a minute companion; R. A. 0h. 0m. 42s.; Dec. N. 58° 16′ 03″. A 2½, whitish; B 11½, dusky. Look directly opposite *Megris*, in the great dipper, through the pole star, and about as far beyond.

3. γ CASSIOPEÆ—A bright star with a distant companion on the right side of the figure; R. A. 0h. 47m. 05s.; Dec. N. 59° 50′ 08″. A 3, brilliant white; B 13, blue. Many small stars in the field.

4. η CASSIOPEÆ—A BINARY STAR, about 4° from α towards Polaris; R. A. 0h. 39m. 27s.; Dec. N. 56° 57′ 09″. A. 4, pale white; B. 7½, purple. Estimated period 700 years.

5. μ CASSIOPEÆ—A coarse TRIPLE STAR in the right elbow; R. A. 0h. 57m. 23s.; Dec. N. 54° 08′ 01″. A 5½, deep yellow; B 14, pale blue; C 11, bluish. Several small stars in the field.

6. σ CASSIOPEÆ—A beautiful double star in the left elbow; R. A. 23h. 50m. 55s.; Dec. N. 54° 51′ 08″. A 6, flushed white; B 8, smalt blue; the colors clear and distinct.

7. A coarse QUADRUPLE STAR, just south of Cepheus' right hand; or about 27° south-south-west of Polaris, on a line drawn over γ Cephei. R. A. 23h. 17m. 45s.; Dec. N. 64° 24′ 03″. A 5, pale yellow; B 9, yellowish; C 11, and D, 13, both blue.

8. A LARGE AND STRAGGLING CLUSTER, between the footstool of Cassiopeia and the head of Cepheus; R. A. 0h. 18m. 10s.; Dec. N. 70° 30′ 03″. A line from γ Cassiopeæ, ⅔ the distance to γ Cephei, will fall upon this object. A coarse double star in the field.

9. A RICH, BUT SOMEWHAT STRAGGLING CLUSTER; R. A. 0h. 24m. 5s.; Dec. N. 62° 23′ 09″. Vicinity splendidly strewed with stars—a double star in the centre. Look near the star κ.

10. A LOOSE CLUSTER, including a small double star; R. A. 0h. 34m. 15s.; Dec. N. 60° 54′ 07″. A 8½, B 11, both pale. Situated just half way between γ and κ.

11. A LOOSE CLUSTER of small stars; R. A. 0h. 58m. 19s.; Dec. N. 60° 44′. On a line from γ towards ε, about ¼ the distance.

12. A CLUSTER and neat double star on a line from α through δ, and about 2½° beyond. In an elegant field of large and small stars.

13. A FINE GALAXY CLUSTER of minute stars, about 3° south-west of β, and about the same distance west of α. R. A. 23h. 49m. 07s.: Dec. N. 55° 49′ 06″. A glorious assemblage, both in extent and richness. Resembles a crab, having spangled rays of stars, spreading over many fields. Map VIII., Fig. 23.

CEPHEUS.—MAP VI.

47. Cepheus is represented on the map as a king, in his royal robe, with a sceptre in his left hand, and a crown of stars upon

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HISTORY?—Who was Cassiopeia? Personal appearance? Sad consequences? Rescue?
TELESCOPIC OBJECTS.—Double and multiple stars? Clusters? What shown on map?
47. How is Cepheus represented? Where situated?

his head. He stands in a commanding posture, with his left foot over the pole, and his sceptre extended towards Cassiopeia, as if for favor and defence of the queen.

"Cepheus illumes
The neighboring heavens; still faithful to his queen,
With thirty-five faint luminaries mark'd."

This constellation is about 25° N. W. of Cassiopeia, near the 2d coil of Draco, and is *on* the meridian at 8 o'clock the 3d of November; but it will linger *near* it for many days. Like Cassiopeia, it may be seen at all hours of the night, when the sky is clear, for to us it never sets.

By reference to the lines on the map, which all meet in the pole, it will be evident that a star, near the pole, moves over a *much less* space in one hour, than one at the equinoctial; and generally, the *nearer* the pole, the *narrower* the space, and the *slower* the motion.

The stars that are so near the pole may be better described by their *polar distance*, than by their declination. By polar distance is meant, the *distance* from the pole, and is what the declination wants of 90°.

48. In this constellation there are 35 stars visible to the naked eye; of these, there glitters on the left shoulder, a star of the 3d magnitude, called *Alderamin*, which with two others of the same brightness, 8° and 12° apart, form a slightly curved line towards the N. E. The last, whose *letter* name is Gamma, is in the right knee, 19° N. of Caph, in Cassiopeia. The middle one in the line is Alphirk, in the girdle. This star is one-third of the distance from Alderamin to the pole, and nearly in the same right line.

It cannot be too well understood that the bearings, or direction of one star from another, as given in this treatise, are strictly applicable only when the latter one is on, or near the meridian. The bearings given, in many cases, are not the least approximations to what appears to be their relative position; and in some, if relied upon, will lead to errors. For example:—It is said in the preceding paragraph, that Gamma, in Cepheus, bears 19° N. of Caph in Cassiopeia. This is true, when Caph is on the meridian, but at this very moment, while the author is writing this line, Gamma *appears* to be 19° *due west* of Caph; and six months hence, will appear to be the same distance *east* of it. The reason is obvious; the circle which Cepheus appears to describe about the pole, is *within* that of Cassiopeia, and consequently when on the east side of the pole, will be *within*, or *between* Cassiopeia and the pole—that is, *west* of Cassiopeia. And for the same reason, when Cepheus is on the west side of the pole, it is *between* that and Cassiopeia, or *east of it*.

Let it also be remembered, that in speaking of the *pole*, which we shall have frequent occasion to do, in the course of this work, the *North Polar Star* or any imaginary point very near it, is always meant; and *not*, as some will vaguely apprehend, a point *in the horizon*, directly N. of us. The true pole of the heavens is always elevated just as many degrees *above* our horizon, as we are *north* of the Equator. If we live in 42° N. latitude, the N. pole will be 42° above our horizon. (*See North Polar Star.*)

49. There are also two smaller stars about 9° E. of Alderamin and Alphirk, with which they form a square; Alderamin being the upper, and Alphirk the lower one on the W. 8° apart. In the *centre* of this square there is a bright dot, or semi-visible star.

The *head* of Cepheus is in the Milky-Way, and may be known

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48. Number of stars visible? Principal stars? Situation? 49. What other stars, and situation? Situation of the *head*, and how known? Distance of this Asterism from the pole star?

by three stars of the 4th magnitude in the crown, which form a small acute triangle, about 9° to the right of Alderamin. The mean polar distance of the constellation is 25°, while that of Alderamin is 28° 10′. The right ascension of the former is 338° ; consequently, it is 22° E. of the equinoctial colure.

The student will understand that right ascension is reckoned on the equinoctial, from the first point of Aries, E., quite round to the same point again, which is 360°. Now, 338° measured from the same point, will reach the same point again, within 22°; which is the difference between 360° and 338°. This rule will apply to any other case.

HISTORY.

This constellation immortalizes the name of the king of Ethiopia. The name of his queen was Cassiopeia. They were the parents of Andromeda, who was betrothed to Perseus. Cepheus was one of the Argonauts who accompanied Jason on his perilous expedition in quest of the golden fleece. Newton supposes that it was owing to this circumstance that he was placed in the heavens; and that not only this, but all the ancient constellations, relate to the Argonautic expedition, or to persons some way connected with it. Thus, he observes, that as Musæus, one of the Argonauts, was the first Greek who made a celestial sphere, he would naturally delineate on it those figures which had some reference to the expedition. Accordingly, we have on our globes to this day, the *Golden Ram*, the ensign of the ship in which Phryxus fled to Colchis, the scene of the Argonautic achievements. We have also the *Bull* with brazen hoofs, tamed by Jason; the *Twins*, Castor and Pollux, two sailors, with their mother *Leda*, in the form of a *Swan*, and *Argo*, the ship itself; the watchful *Dragon*, Hydra, with the *Cup* of Medea, and a raven upon its carcase, as an emblem of death; also *Chiron*, the Master of Jason, with his *Altar* and *Sacrifice; Hercules*, the Argonaut, with his *club*, his *dart*, and *vulture*, with the *dragon*, *crab*, and *lion* which he slew; and *Orpheus*, one of the company, with his *harp*. All these, says Newton, refer to the Argonauts.

Again; we have *Orion*, the son of Neptune, or, as some say, the grandson of Minos, with his *dogs*, and *hare*, and *river*, and *scorpion*. We have the story of Perseus in the constellation of that name, as well as in Cassiopeia, Cepheus, Andromeda, and Cetus; that of Calisto and her son Arcas, in *Ursa Major*; that of Icarius, and his daughter Erigone, in *Bootes* and *Virgo*. *Ursa Minor* relates to one of the nurses of Jupiter; *Auriga*, to Erichtonius; *Ophiuchus*, to Phorbas; *Sagittarius*, to Crolus, the son of one of the Muses; *Capricorn*, to Pan, and *Aquarius* to Ganymede. We have also Ariadne's *crown*, Bellerophon's horse, Neptune's *dolphin*, Ganymede's *eagle*, Jupiter's *goat*, with her *kids*, the asses of *Bacchus*, the *fishes* of Venus and Cupid, with their parent, the *southern fish*. These, according to Deltoton, comprise the Grecian constellations mentioned by the poet Aratus; and all relate, as Newton supposes, remotely or immediately to the Argonauts.

It may be remarked, however, that while none of these figures refer to any transactions of a later date than the Argonautic expedition, yet the great disagreement which appears in the mythological account of them, proves that their invention must have been of greater antiquity than that event, and that these constellations were received for some time among the Greeks, before their poets referred to them in describing the particulars of that memorable expedition.

TELESCOPIC OBJECTS.

1. α Cephei (*Alderamin*)—A fine star, with a distant companion on the left shoulder of Cepheus; R. A., 21h. 15m.; Dec., 61° 54′. It is about half way between Polaris and Deneb, and 8° south-west from β Cephei. A 3, white; B 10, pale blue, with a companion of the same magnitude and color.

2. β Cephei (*Alphirk*)—A double star on the left side of the girdle of Cepheus, two-thirds of the distance from Polaris to Alderamin. A 3, white; B 8, blue, with a very minute double star preceding.

3. γ Cephei (*Er Rai*)—A double star in the knee of Cepheus, with a distant telescopic companion on the preceding parallel. A 3, yellow; B 14, dusky. R. A., 23h. 32m. 47s.; Dec., N. 76° 44′ 7″. This star will be the Pole star in about 2360 years.

History.—Who was Cepheus? Why placed in the heavens? What said of the origin of other constellations?

Telescopic Objects.—Alpha? Beta, &c.? What clusters?

4. δ Cephei (*Var*) in the crown of Cepheus, a fine, though wide DOUBLE STAR; R. A. 22h. 23m. 14s.; Dec., N. 57° 35′ 9″. A 4½, orange tint; B 7, fine blue—the colors in fine contrast. This star is *variable*, with a period of 5d. 8h. 30m.

5. A LARGE AND RICH CLUSTER on the left elbow; R. A., 20h. 28m. 17s.; Dec., N. 60° 06 2″. It is 12° due north of α Cygni; and 3° west-south-west of η Cephei. "A grand but distant collocation of suns bound together by mutual relations."

3. AN IRREGULAR CLUSTER between the head of Cepheus and the chain of Andromeda; R. A., 23h. 17m. 10s.; Dec., N. 60° 43′ 1″. It is about one-third of the distance from β Cassiopeæ to α Cephei; and may be seen on Map VI., near the sceptre of Cepheus. For a telescopic view, see Map VIII., Fig. 24.

CHAPTER II.

CONSTELLATIONS ON THE MERIDIAN IN DECEMBER.

ARIES (THE RAM).—MAP II.

50. TWENTY-TWO centuries ago, as Hipparchus informs us, this constellation occupied the *first sign* in the ecliptic, commencing at the vernal equinox. But as the constellations gain about 50″ on the equinox, at every revolution of the heavens,* they have advanced in the ecliptic nearly 31° beyond it, or more than a whole sign: so that the Fishes now occupy the same place in the Zodiac, that Aries did in the time of Hipparchus; while the *constellation* Aries is now in the *sign* Taurus, Taurus in Gemini, and Gemini in Cancer, and so on.

ARIES is therefore now the second constellation in the Zodiac. It is situated next east of Pisces, and is midway between the Triangles and the Fly on the N. and the head of Cetus on the S. It contains 66 stars, of which, one is of the 2d, one of the 3d, and two of the 4th magnitudes.

"First, from the east, the Ram conducts the year;
Whom Ptolemy with *twice nine* stars adorns,
Of which two only claim the second rank;
The rest, when Cynthia fills the sign, are lost."

Aries is readily distinguished by means of two bright stars in the head, about 4° apart, the brightest being the most north-easterly of the two. The first, which is of the 2d magnitude, situated in the right horn, is called Alpha Arietis, or simply *Arietis;* the other, which is of the 3d magnitude, lying near the left horn, is called Sheratan, and may be known by another star of the 4th magnitude, in the ear, 1½° S. of it, called *Mesarthim*, which is the *first* star in this constellation.

Arietis and Sheratan, are one instance out of many, where stars of more than ordinary brightness are seen together *in pairs*, as in the Twins, the Little Dog, &c., the brightest star being commonly on the east.

* See "Precession of the Equinoxes," page 270.

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50. Constellations in this chapter? Aries 22 centuries ago? Now; and why? How distinguished? Arietis and Sheratan?

51. The position of Arietis affords important facilities to nautical science. Difficult to comprehend as it may be, to the unlearned, the skilful navigator who should be lost upon an unknown sea, or in the midst of the Pacific ocean, could, by measuring the distance between Arietis and the Moon, which often passes near it, determine at once not only the spot he was in, but his true course and distance to any known meridian or harbor on the earth. See Part II., page 206.

Arietis comes to the meridian about 12 minutes after Sheratan, on the 5th December, near where the sun does in midsummer. Arietis, also, is nearly on the same meridian with Almaack, in the foot of Andromeda, 19° N. of it, and culminates only four minutes after it. The other stars in this constellation are quite small, constituting that loose cluster which we see between the Fly on the north, and the head of Cetus on the south.

When Arietis is on the meridian, Andromeda and Cassiopeia are a little past the meridian, nearly overhead, and Perseus with the head of Medusa, is as far to the east of it. Taurus and Auriga are two or three hours lower down; Orion appears in the S. E., and the Whale on the meridian, just below Aries, while Pegasus and the Swan are seen half-way over in the west.

The manner in which the ancients divided the Zodiac into 12 equal parts, was both simple and ingenious. Having no instrument that would measure time exactly, "they took a vessel, with a small hole in the bottom, and having filled it with water, suffered the same to distill, drop by drop, into another vessel set beneath to receive it, beginning at the moment when some star rose, and continuing till it rose the next following night, when it would have performed one complete revolution in the heavens. The water falling down into the receiver they divided into twelve equal parts; and having twelve other small vessels in readiness, each of them capable of containing one part, they again poured all the water into the upper vessel, and observing the rising of some star in the Zodiac, at the same time suffered the water to drop into one of the small vessels. And as soon as it was full, they removed it, and set an empty one in its place. Just as each vessel was full, they took notice what star of the Zodiac rose at that time, and thus continued the process through the year, until the 12 vessels were filled."

Thus the Zodiac was divided into 12 equal portions, corresponding to the 12 months of the year, commencing at the vernal equinox. Each of these portions served as the visible representative or *sign* of the month it appeared in.

All those stars in the Zodiac which were observed to rise while the first vessel was filling, were constellated and included in the first sign, and called *Aries*, an animal held in great esteem by the shepherds of Chaldea. All those stars in the Zodiac which rose while the second vessel was filling, were constellated and included in the second sign, which, for a similar reason, was denominated *Taurus;* and all those stars which were observed to rise while the third vessel was filling, were constellated in the *third* sign, and called Gemini, in allusion to the *twin season* of the flocks.

Thus each sign of 30° in the Zodiac, received a distinctive appellation, according to the fancy or superstition of the inventors; which names have ever since been retained, although the constellations themselves have since left their nominal signs more than 30° behind. The sign Aries, therefore, included all the stars embraced in the first 30° of the Zodiac, and no more. The sign Taurus, in like manner, included all those stars embraced

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51. Position of Arietis? Importance to mariners? When come to meridian? Where Andromeda and Cassiopeia then? Perseus? Taurus, Auriga, Orion, Pegasus and Swan? What of other stars in Aries? Ancient method of dividing the Zodiac? Names of signs?

in the next 30° of the Zodiac, or those between 30° and 60°, and so of the rest. Of those who imagine that the twelve constellations of the Zodiac refer to the twelve tribes of Israel, some ascribe Aries to the tribe of Simeon, and others, to Gad.

HISTORY.

According to fable, this is the ram which bore the golden fleece, and carried Phryxus and his sister Helle through the air, when they fled to Colchis from the persecution of their stepmother Ino. The rapid motion of the ram in his aerial flight high above the earth, caused the head of Helle to turn with giddiness, and she fell from his back into that part of the sea which was afterwards called *Hellespont*, in commemoration of the dreadful event. Phryxus arrived safe at Colchis, but was soon murdered by his own father-in-law, Æetes, who envied him his golden treasure. This gave rise to the celebrated Argonautic expedition under the command of Jason, for the recovery of the golden fleece.

Nephele, Queen of Thebes, having provided her children, Phryxus and Helle, with this noble animal, upon which they might elude the wicked designs of those who sought their life, was afterwards changed into a cloud, as a reward for her parental solicitude; and the Greeks ever after called the clouds by her name. But the most probable account of the origin of this constellation is given in a preceding paragraph, where it is referred to the flocks of the Chaldean shepherds.

During the campaigns of the French army in Egypt, General Dessaix discovered among the ruins at Dendera, near the banks of the Nile, the great temple supposed by some to have been dedicated to Isis, the female deity of the Egyptians, who believed that the rising of the Nile was occasioned by the tears which she continually shed for the loss of her brother Osiris, who was murdered by Typhon. Others suppose this edifice was erected for astronomical purposes, from the circumstance that *two Zodiacs* were discovered, drawn upon the ceiling, on opposite sides. On both these Zodiacs the equinoctial points are in Leo, and not in Aries; from which it has been concluded, by those who pertinaciously endeavor to array the arguments of science against the chronology of the Bible and the validity of the Mosaic account, that these Zodiacs were constructed when the sun entered the sign Leo, which must have been 9720 years ago, or 4000 years before the inspired account of the creation. The infidel writers in France and Germany make it 10,000 years before. But we may "set to our seal," that whatever is true in fact and correct in inference on this subject will be found, in the end, not only consistent with the Mosaic record, but with the common meaning of the expressions it uses.

The discovery of Champollion has put this question for ever at rest; and M. Latronne, a most learned antiquary, has very satisfactorily demonstrated that these Egyptian Zodiacs are merely the horoscopes of distinguished personages, or the precise situation of the heavenly bodies in the Zodiac at their nativity. The idea that such was their purpose and origin, first suggested itself to this gentleman on finding, in the box of a mummy, a similar Zodiac, with such inscriptions and characters as determined it to be the horoscope of the deceased person.

Of all the discoveries of the antiquary among the relics of ancient Greece, the ruins o. Palmyra, the gigantic pyramids of Egypt, the temples of their gods, or the sepulchres of their kings, scarcely one so aroused and riveted the curiosity of the learned, as did the discovery of Champollion the younger, which *deciphers the hieroglyphics* of ancient Egypt.

The potency of this invaluable discovery has already been signally manifested in settling a formidable controversy between the champions of infidelity and those who maintain the Bible account of the creation. It has been shown that the constellation *Pisces*, since the days of Hipparchus, has come, by reason of the annual precession, to occupy the same apparent place in the heavens that Aries did two thousand years ago. The Christian astronomer and the infidel are perfectly agreed as to the *fact*, and the *amount* of this yearly gain in the apparent motion of the stars. They both believe, and both can demonstrate, that the fixed stars have gone forward in the Zodiac about 50″ of a degree in every revolution of the heavens since the creation; so that were the world to light upon any authentic inscription or record of past ages, which should give the true position or longitude of any particular star at that time, it would be easy to fix an unquestionable date to such a record. Accordingly, when the famous "Egyptian Zodiacs," which were sculptured on the walls of the temple at Dendera, were brought away *en masse*, and exhibited in the Louvre at Paris, they enkindled a more exciting interest in the thousands who saw them, than ever did the entrance of Napoleon. "Educated men of every order, and those who had the vanity to think themselves such," says the commentator of Champollion, "rushed to behold *the Zodiacs*. These Zodiacs were immediately published and commented upon, with more or less good faith and decorum.

HISTORY.—Discovery in Egypt? Use made of the Zodiacs? What did they prove to be? How ascertained? Who most zealous in opposing revelation? Means employed?

Science struck out into systems very bold; and the spirit of infidelity, seizing upon the discovery, flattered itself with the hope of drawing from thence new support. It was unjustifiably taken for granted, that the ruins of Egypt furnished astronomy with monuments, containing observations that exhibited the state of the heavens in the most remote periods. Starting with this assumption, a pretence was made of demonstrating by means of calculations received as infallible, that the celestial appearances assigned to these monuments extended back from forty-five to sixty-five centuries; that the Zodiacal system to which they must belong, dated back fifteen thousand years, and must reach far beyond the limits assigned by Moses to the existence of the world." Among those who stood forth more or less bold as the adversaries of Revelation, the most prominent was M. Dupuis, the famous author of *L'origine de tous les Cultes.*

The infidelity of Dupuis was spread about by means of pamphlets, and the advocates of the Mosaic account were scandalized "until a new Alexander arose to cut the Gordian knot, which men had vainly sought to untie. This was Champollion the younger, armed with his discovery." The hieroglyphics now speak a language that all can understand, and no one gainsay. "The Egyptian Zodiacs, then," says Latronne, "relate in no respect to astronomy, but to the idle phantasies of judicial astrology, as connected with the destinies of the emperors who made or completed them."

TELESCOPIC OBJECTS.

1. α ARIETIS—A DOUBLE STAR in the Ram's forehead; R. A. 1h. 58m. 10s; Dec. N. 22° 42′ 02″. A 3, yellow; B 11, purple.

Two thousand years ago the first meridian or Vernal Equinox passed through th' star; but the recession of the equinox at the slow rate of 50″ per year, has, in that lengtl of time, carried the equinoctial nearly 60° to the west, where we now find it. See thi. subject explained in the second part of the book.

2. β ARIETIS (*Sheratan*)—A BRIGHT STAR with a distant companion in the coil of the right horn; R. A. 1h. 45m. 49s.; Dec. N. 20° 01′ 04″. A 3, pearly white; B 11, dusky.

3. γ ARIETIS (*Mesarthim*)—a DOUBLE STAR just south of β; R. A. 1h. 44m. 45s.; Dec. N. 18° 30′ 05″. A 4½, bright white; B 5, pale grey. A fine object. Map VIII., Fig. 2.

4. ε ARIETIS—A VERY CLOSE DOUBLE STAR near the root of the tail, and between it and Musca; R. A. 2h. 50m. 04s.; Dec. N. 20° 41′ 08″. A 5, pale yellow; B 6½, whitish. It requires a good telescope to separate them.

5. π ARIETIS—A neat TRIPLE STAR in the haunch, about one-third of the distance from β Arietis to Aldebaran; R. A. 2h. 40m. 22s.; Dec. N. 16° 47′ 08″. A 5, pale yellow; B 8½, flushed; C 11, dusky. A beautiful trio.

6. A QUADRUPLE STAR half way between α and γ under the right horn; R. A. 1h. 50m. 43s.; Dec. N. 20° 16′ 07″. A 6, topaz yellow; B 15, deep blue; C 10, lilac; D, pale blue. An exquisite object.

7. A ROUND NEBULA near γ Arietis, and just east of it; R. A. 1h. 50m. 34s.; Dec. N 18° 13′ 06″. It is large and pale, and lies among some small stars, some of which form a curve across the south part of the field.

TRIANGULÆ (THE TRIANGLES).—MAP II.

52. The Triangles are situated between the head of Aries on the north, and the feet of Andromeda on the south. R. A. 2h.; Dec. N. 30°. They contain two stars of the 4th magnitude, and two of the 5th; with several smaller. A line from Sheratan in Aries, to Almaack, will pass through the *lucida Trianguli,* about midway between them.

TELESCOPIC OBJECTS? What α Arietis? Other double stars? Triple? Quadruple? Any clusters? Nebulæ?

52. Situation of the Triangles? Number and size of stars? How find their lucida?

HISTORY.

The upper or Northern Triangle is one of the ancient 48 asterisms; and Hevelius took three other stars between it and the head of Aries, to form *Triangulum minus*. The latter figure, however, is discontinued, though shown on the map.

TELESCOPIC OBJECTS.

1 α TRIANGULI—A bright FOURTH MAGNITUDE STAR, with a Telescopic companion; R. A. 1h. 43m. 58s.; Dec. N. 28° 47′ 08″. A 3½, yellow; B 11, lilac.

2. ε TRIANGULI—A MOST DELICATE DOUBLE STAR; R. A. 1h. 53m. 38s.: Dec. N. 32° 30′ 05″. A 5½, bright yellow; B 15, dusky.

3. A large and distinct but faint PALE WHITE NEBULA, between the Triangles and the head of the Northern Fish; R. A. 1h. 24m. 51s.; Dec. N. 29° 51′ 03″. A bright star a little north-west, and five others more remote in the east.

MUSCA (THE FLY).—MAP II.

53. This very small constellation lies directly between the back of Aries on the south, and the head of Medusa on the north. It has one star of the 2d, two of the 4th, and two of the 5th magnitudes. An unimportant asterism, and not always mentioned in the catalogues, though shown on the map.

TELESCOPIC OBJECTS.

1. A FINE DOUBLE STAR over the back of Aries, nearly midway between the Pleiades and β Andromedæ; R. A. 2h. 31m. 20s.; Dec. N. 26° 22′ 02″. A 6, pale topaz; B 9, light blue. An easy object.

2. α MUSCÆ—a COARSE QUADRUPLE STAR, in the body of the figure, and forming its lucida; R. A. 2h. 40m. 34s.; Dec. N. 26° 35′ 09″. A 3, white; B 13, deep blue; C 11, lurid; D 9, pale grey. Both these objects are usually classed as belonging to Aries.

CETUS (THE WHALE).—MAP II.

54. As the whale is the chief monster of the deep, and the largest of the aquatic race, so is it the largest constellation in the heavens. It occupies a space of 50° in length, E. and W., with a mean breadth of 20° from N. to S. It is situated below Aries and the Triangles, with a mean declination of 12° S. It is represented as making its way to the E., with its body below, and its head elevated above the equinoctial; and is six weeks in passing the meridian. Its tail comes to the meridian on the 10th of November, and its head leaves it on the 22d of December.

55. This constellation contains 97 stars; two of the 2d magnitude, ten of the 3d, and nine of the 4th. The head of Cetus

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HISTORY.—Which ancient? Who formed the other? Now recognized, or not? TELESCOPIC OBJECTS? Double stars? Nebulæ?

53. Situation of Musca? Stars? Relative importance? Is it always recognized as a constellation? 54. Cetus? Comparative size? Situation? How represented? 55. Number of stars? Magnitudes? How may the head of Cetus be known? Brightest

may be readily distinguished, about 20° S. E. of Aries, by means of five remarkable stars, 4° and 5° apart, and so situated as to form a regular pentagon. The brightest of these is Menkar, of the 2d magnitude, in the nose of the Whale. It occupies the S. E. angle of the figure. It is 3½° N. of the equinoctial, and 15° E. of El Rischa in the bight of the cord between the Two Fishes. It is directly 37° S. of Algol, and nearly in the same direction from the Fly. It makes an equilateral triangle with Arietis and the Pleiades, being distant from each about 23° S., and may otherwise be known by a star of the 3d magnitude in the mouth, 3° W. of it, called *Gamma*, placed in the south middle angle of the pentagon.

56. *Nu* is a star of the 4th magnitude, 4° N. W. of Gamma, and these two constitute the S. W. side of the pentagon in the head of the Whale, and the N. E. side of a similar oblong figure in the neck.

Three degrees S. S. W. of Gamma, is another star of the 3d magnitude in the lower jaw, marked Delta, constituting the E. side of the oblong pentagon ; and 6° S. W. of this, is a noted star in the neck of the Whale, called *Mira*, or the "wonderful star of 1596," which forms the S. E. side. This variable star was first noticed as such by Fabricius, on the 13th of August, 1596. It changes from a star of the 2d magnitude so as to become invisible once in 234 days, or about 7 times in 6 years. Herschel makes its period 331 days, 10 hours, and 19 minutes ; while Hevelius assures us that it once disappeared for 4 years ; so that its true period, perhaps, has not been satisfactorily determined.

The whole number of stars ascertained to be variable amounts to only 15; while those which are suspected to be variable, amount to 37.

57. Mira is 7° S. S. E. of El Rischa, in the bend or knot of the ribbon which connects the Two Fishes. Ten degrees S. of Mira, are 4 small stars, in the breast and paws, about 3° apart, which form a square, the brightest being on the E. Ten degrees S. W. of Mira is a star of the 3d magnitude, in the heart, called *Baten Kaitos*, which makes a scalene triangle with two other stars of the same magnitude 7° and 10° W. of it ; also, an equilateral triangle with Mira and the easternmost one in the square.

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star? Position? Name? 56. Size and Position of Nu? Delta? Mira? Position? Peculiarity? When, and by whom first noticed? Period and extent of variability? Whole number of variable stars? 57. *Baten Kaitos?* Position with regard to Mira. To other stars?

A great number of geometrical figures may be formed from the stars in this, and in most of the other constellations, merely by reference to the maps; but it is better that the student should exercise his own ingenuity in this way with reference to the stars themselves, for when once he has constructed a group into any letter or figure of his own invention, he never will forget it.

The teacher should therefore require his class to commit to writing the result of their own observations upon the relative position, magnitude and figures of the principal stars in each constellation. One evening's exercise in this way will disclose to the student a surprising multitude of *crosses*, *squares*, *triangles*, *arcs* and *letters*, by which he will be better able to identify and remember them, than by any instructions that could be given.

For example: Mira and Baten in the Whale, about 10° apart, make up the S. E. or shorter side of an irregular square, with El Rischa in the node of the ribbon, and another star in the Whale as far to the right of Baten, as El Rischa is above Mira. Again,

There are three stars of equal magnitude, forming a straight line W. of Baten; from which, to the middle star is 10°, thence to the W. one 12½; and 8° or 9° S. of this line, in a triangular direction, is a bright star of the second magnitude in the coil of the tail, called Diphda.

In a southerly direction, 25° below Diphda, is Alpha in the head of the Phenix, and about the same distance S. W. is Fomalhaut, in the mouth of the Southern Fish, forming together a large triangle, with Diphda in the vertex or top of it.

That fine cluster of small stars S. of the little square in the Whale, constitutes a part of a new constellation called the *Chymical Furnace*. The two stars N. E., and the three to the southward of the little square, are in the river *Eridanus*.

HISTORY.

This constellation is of very early antiquity: though most writers consider it the famous sea-monster sent by Neptune to devour Andromeda because her mother Cassiopeia had boasted herself fairer than Juno or the Sea Nymphs; but slain by Perseus and placed among the stars in honor of his achievement.

> "The winged hero now descends, now soars,
> And at his pleasure the vast monster gores.
> Deep in his back, swift stooping from above,
> His crooked sabre to the hilt he drove."

It is quite certain, however, that this constellation had a place in the heavens long prior to the time of Perseus. When the equinoctial sun in Aries, which is right over the head of Cetus, opened the year, it was denominated the *Preserver*, or *Deliverer*, by the idolaters of the East. On this account, according to Pausanius, the sun was worshipped, at Eleusis, under the name of the *Preserver* or *Saviour*.

> "With gills pulmonic breathes the enormous whale,
> And spouts aquatic columns to the gale;
> Sports on the shining wave at noontide hours,
> And shifting rainbows crest the rising showers."—*Darwin*.

TELESCOPIC OBJECTS.

1. β CETI—A DOUBLE STAR; R. A. 0h. 35m. 34s.; Dec. S. 18° 51′ 9″. A 2½, yellow; B 12, pale blue.

2. γ CETI—A CLOSE DOUBLE STAR in the Whale's mouth; R. A. 2h. 35m. 01s.; Dec. N. 2° 33′ 5″. A 3, pale yellow; B 7, lucid blue; the colors finely contrasted.

3. ν A DOUBLE STAR in the Whale's eye; γ R. A. 2h. 27m. 29s.; Dec. N. 4° 53′ 5″. A 4½, pale yellow; B 15, blue.

4. A LONG NARROW NEBULA, of a pale, milky tint; R. A. 0h. 39m. 45s.; Dec. S. 26° 10′ 1″. It is situated in the space south of the tail of Cetus, near a line drawn from α Andromeda to β Ceti. Discovered by Miss Herschel, in 1783.

5. A PLANETARY NEBULA; R. A. 2h. 19m. 25s.; Dec. S. 1° 51′ 6″; in the middle of the Whale's neck.

6. A BRIGHT ROUND NEBULA; R. A. 1h. 23m. 29s.; Dec. S. 7° 41′ 8″. Registered by Sir W. Herschel, 1785. It is just above the Whale's back.

HISTORY.—Antiquity? Its original name? When, and why? What worship in consequence?

TELESCOPIC OBJECTS.—Beta? Gamma? Nu? Nebulæ?

7. A ROUND STELLAR NEBULA, near δ in the Whale's lower jaw, and about 2½° from γ on a line towards ε, or south by west. A very *distant* object, classed by Sir W. Herschel, as 910 times as distant as stars of the first magnitude.

PERSEUS, ET CAPUT MEDUSÆ.—MAP III. AND IV.

58. PERSEUS is represented with a sword in his right hand, the head of Medusa in his left, and wings at his feet. It is situated directly N. of the Pleiades and the Fly, between Andromeda on the W. and Auriga on the E. Its mean declination is 46° N. It is on the meridian the 24th of December. It contains, including the head of Medusa, 59 stars, two of which are of the 2d magnitude, and four of the 3d. According to Eudosia, it contains, including the head of Medusa, 67 stars.

——————"Perseus next,
Brandishes high in heaven his sword of flame,
And holds triumphant the dire Gorgon's head,
Flashing with fiery snakes! the stars he counts
Are *sixty-seven;* and two of these he boasts,
Nobly refulgent in the *second* rank—
One in his vest, one in Medusa's head."

59. THE HEAD OF MEDUSA is not a separate constellation, but forms a part of Perseus. It is represented as the trunkless head of a frightful Gorgon, crowned with coiling snakes, instead of hair, which the victor Perseus holds in his hand. There are, in all, about a dozen stars in the head of Medusa; three of the 4th magnitude, and one, varying alternately from the 2d to the 4th magnitude. This remarkable star is called *Algol.* It is situated 12° E. of Almaack, in the foot of Andromeda, and may be known by means of three stars of the 4th magnitude, lying a few degrees S. W. of it, and forming a small triangle. It is on the meridian the 21st of December; but as it continues above the horizon 18 hours out of 24, it may be seen every evening from September to May. It varies from the 2d to the 4th magnitude in about 3½ hours, and back again in the same time; after which it remains steadily brilliant for 2¾ days, when the same changes recur.

The periodical variation of Algol was determined in 1783, by John Goodricke, of York (Eng.), to be 2 days, 20 hours, 48 minutes, and 56 seconds. Dr. Herschel attributes the variable appearance of Algol to spots upon its surface, and thinks it has a motion on its axis similar to that of the *sun.* He also observes, of variable stars generally:—"The rotary motion of the stars upon their axis is a capital feature in their resemblance to the sun. It appears to me now, that we cannot refuse to admit such a motion, and that indeed it may be as evidently proved as the diurnal motion of the earth. Dark spots,

58. Perseus? How represented? When on the meridian? Number of stars? Size? 59. Head of Medusa? How represented? Number of stars? What remarkable one? Situation? Variableness and period? When and by whom determined? Supposed cause of variability? Lalande?

or large portions of the surface less luminous than the rest, turned alternately in certain directions either toward, or from us, will account for all the phenomena of periodical changes in the lustre of the stars, so satisfactorily, that we certainly need not look out for any other cause."

It is said that the famous astronomer Lalande, who died at Paris in 1807, was wont to remain whole nights, in his old age, upon the *Pont Neuf*, to exhibit to the curious the variations in the brilliancy of the star Algol.

60. Nine degrees E. by N. from Algol, is the bright star *Algenib*, of the 2d magnitude, in the side of Perseus, which with Almaack, makes a perfect right angle at Algol, with the open part towards Cassiopeia. By means of this strikingly perfect figure, the three stars last mentioned may always be recognized without the possibility of mistaking them. Algenib may otherwise be readily distinguished by its being the brightest and middle one of a number of stars lying four and five degrees apart, in a large semicircular form, curving towards Ursa Major.

Algenib comes to the meridian on the 21st December, 15 minutes after Algol, at which time the latter is almost directly overhead. When these two stars are on the meridian, that beautiful cluster, the Pleiades, is about half an hour E. of it; and in short, the most brilliant portion of the starry heavens is then visible in the eastern hemisphere. The glories of the scene are unspeakably magnificent; and the student who fixes his eye upon those lofty mansions of being, cannot fail to covet a knowledge of their order and relations, and to "reverence Him who made the Seven Stars and Orion."

61. The Milky Way around Perseus is very vivid, being undoubtedly a rich stratum of fixed stars, presenting the most wonderful and sublime phenomenon of the Creator's power and greatness. Kohler, the astronomer, observed a beautiful nebula near the face of Perseus, besides eight other nebulous clusters in different parts of the constellation.

The head and sword of Perseus are exhibited on the circumpolar map. That very bright star 23° E. of Algol, is Capella in the Charioteer.

HISTORY

Perseus was the son of Jupiter and Danae. He was no sooner born than he was cast into the sea, with his mother; but being driven on the coasts of one of the islands of the Cyclades, they were rescued by a fisherman, and carried to Polydectes, the king of the place, who treated them with great humanity, and intrusted them to the care of the priests of Minerva's temple. His rising genius and manly courage soon made him a favorite of the gods. At a great feast of Polydectes, all the nobles were expected to present the king with a superb and beautiful horse; but Perseus, who owed his benefactor much, not wishing to be thought less munificent than the rest, engaged to bring him the head of Medusa, the only one of the three Gorgons, who was subject to mortality. The names of the other two were Stheno and Euryale. They were represented with serpents wreathing round their heads instead of hair, having yellow wings and brazen hands; their bodies which grew indissolubly together, were covered with impenetrable scales, and their very looks had the power of turning into stones all those on whom they fixed their eyes.

To equip Perseus for this perilous enterprise, Pluto, the god of the infernal regions, lent him his helmet, which had the power of rendering the wearer invisible. Minerva, the goddess of wisdom, furnished him with her buckler, which was as resplendent as a polished mirror; and he received from Mercury wings for his feet, and a dagger made

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60. Algenib? How known? When on the meridian? Where, then, are the Pleiades? What the general aspect of the heavens? 61. Milky Way around Perseus? Observation of Kohler?

HISTORY.—Who was Perseus? What fate at birth, &c.?

of diamonds. Thus equipped, he mounted into the air, conducted by Minerva, and came upon the monsters who, with the watchful snakes about their heads, were all asleep. He approached them, and with a courage which amazed and delighted Minerva, cut off with one blow Medusa's head. The noise awoke the two immortal sisters, but Pluto's helmet rendered Perseus invisible, and the vengeful pursuit of the Gorgons proved fruitless.

> "In the mirror of his polished shield
> Reflected, saw Medusa slumbers take,
> And not one serpent by good chance awake;
> Then backward an unerring blow he sped,
> And from her body lopped at once her head."

Perseus then made his way through the air, with Medusa's head yet reeking in his hand, and from the blood which dropped from it as he flew, sprang all those innumerable serpents that have ever since infested the sandy deserts of Libya.

> "The victor Perseus, with the Gorgon head,
> O'er Libyan sands his airy journey sped,
> The gory drops distilled, as swift he flew,
> And from each drop envenomed serpents grew."

The destruction of Medusa rendered the name of Perseus immortal, and he was changed into a constellation at his death, and placed among the stars, with the head of Medusa by his side.

TELESCOPIC OBJECTS.

1. α Persei—A fine double star; R. A. 3h. 12m. 55s.; Dec. N. 49° 17′ 2″. A 2½, brilliant lilac; B 9, cinereous. This is *Algenib*, in the hero's *left* side.

2. β Persei, or *Algol*; R. A. 2h. 57m. 46s.; Dec. N. 41° 20′. A variable double star. A 2 to 4, whitish; B 11, purple. The former varies in brightness periodically, from the 2d to the 4th magnitude, and back again to the 2d magnitude, period being 2d. 20h. 48m. 56s.; an object of great interest.

3. γ Persei—A wide unequal double star in the hero's left shoulder; R. A. 2h. 53m. 14s.; Dec. N. 52° 52′ 4″. A 4, flushed white; B 14, clear blue.

4. δ Persei—A bright star with a companion in the hero's hip; R. A., 3h. 31m. 33s.; Dec., N. 47° 16′ 2″. About 3° south-west of α Persei. A 3½, white; B 11, pale blue.

5. ε Persei—A neat double star in the right knee; R. A. 3h. 47m. 08s.; Dec. N. 39° 32′ 4″. A 3½, pale white; B 9, lilac; a fine delicate object.

6. ξ Persei—A delicate quadruple star; R. A. 3h. 44m. 05s.; Dec. N. 31° 24′ 2″. A 3½, flushed white; B 10, smalt blue; C 12, ash-colored; D 11, blue. It is situated in the right foot, and is designated by Smyth as "an elegant group."

7. η Persei—A fine double star in the head of the figure; R. A. 2h. 39m. 04s.; Dec. N. 55° 13′ 5″. A 5, orange; B 8½, smalt blue; the colors in fine contrast.

8. A gorgeous cluster in the sword handle of Perseus; R. A. 2h. 08m. 58s.; Dec. N. 56° 24′ 4″. It may be seen with the naked eye, and when seen through a good telescope, is one of the most magnificent objects in the heavens. Map VIII., Fig. 25.

9. An extensive and rich cluster on the right side of Perseus, in a rich portion of the galaxy. R. A. 3h. 04m. 01s.; Dec. N. 46° 37′ 9″. Smyth says "it has a gathering spot about 4′ in diameter, where the star-dust glows among minute points of light." Herschel says, "the large stars are arranged in lines like interwoven letters.

10. An elongated nebula; R. A. 2h. 30m. 25s.; Dec. N. 38° 21′ 3″; supposed to be a vast ring, seen obliquely. Map VIII., Fig. 26.

11. A pretty compressed oval group of stars, in the left knee of Perseus, nearly midway between λ and μ; R. A. 3h. 58m. 11s.; Dec. N. 49° 04′ 05″. A well-marked object, surrounded by a curve of larger stars, somewhat in the form of the letter D. Map VIII., Fig. 27.

Telescopic Objects.—Alpha? Beta? Gamma? Delta? Epsilon? Zeta? Eta? Clusters? Nebula? Which shown on the map?

CHAPTER III.

CONSTELLATIONS ON THE MERIDIAN IN JANUARY.

TAURUS (THE BULL).—MAP III.

62. TAURUS is represented in an attitude of rage, as if about to plunge at Orion, who seems to invite the onset by provocations of assault and defiance. Only the head and shoulders of the animal are to be seen; but these are so distinctly marked that they cannot be mistaken.

The constellations which pass our meridian in the months of January, February and March, present to us the most brilliant and interesting portion of the heavens; embracing an annual number of stars of the highest order and brightness, all so conspicuously situated, that the most inexperienced can easily trace them out.

63. Taurus is now the *second sign* and *third constellation* of the Zodiac; but anterior to the time of Abraham, or more than 4000 years ago, the vernal equinox took place, and the year opened when the sun was in Taurus; and the Bull, for the space of 2000 years, was the prince and leader of the celestial host. The Ram succeeded next, and now the Fishes lead the year. The head of Taurus sets with the sun about the last of May, when the opposite constellation, the Scorpion, is seen to rise in the S. E. It is situated between Perseus and Auriga on the north, Gemini on the east, Orion and Eridanus on the south, and Aries on the west, having a mean declination of 16° N.

64. Taurus contains 141 visible stars, including two remarkable clusters called the PLEIADES and HYADES. The first is now on the shoulder, and the latter in the face of the Bull. The names of the Pleiades are Alcione, Merope, Maia, Electra, Tayeta, Sterope and Celeno. Merope was the only one who married a mortal, and on that account her star is dim among her sisters. Although but six of these are visible to the naked eye, yet Dr. Hook informs us that, with a twelve feet telescope, he saw 78 stars; and Rheita affirms that he counted 200 stars in this small cluster. For its appearance through an ordinary telescope, see Map VIII., Fig. 28.

The most ancient authors, such as Homer, Attalus, and Geminus, counted only *six* Pleiades; but Simonides, Varro, Pliny, Aratus, Hipparchus, and Ptolemy, reckon them

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62. How is Taurus represented? How much of him seen? What constellations most brilliant? 63. In what *sign* is Taurus? What constellation? How 4000 years ago? What next led the year? What now? At what time does Taurus set with the sun? How situated? 64. How many visible stars in Taurus? Clusters? How situated? Names of the Pleiades? What said of Merope? How many of the Pleiades visible to the naked eye? Dr. Hook and Rheita? Ancient authors?

seven in number; and it was asserted, that the seventh had been seen before the burning of Troy; but this difference might arise from the difference in distinguishing them with the naked eye.

65. The Pleiades are so called from the Greek word, πλεειν *pleein*, to *sail;* because at this season of the year, they were considered "the star of the ocean" to the benighted mariner.

Virgil who flourished 1200 years before the invention of the magnetic needle, says that the stars were relied upon, in the first ages of nautical enterprise, to guide the rude bark over the seas.

> "Tunc alnos primum fluvii sensere cavatas;
> Navita tum stellis numeros, et nomina fecit,
> Pleiadas, Hyadas, claramque Lycaonis Arcton."

> "Then first on seas the shallow alder swam;
> Then sailors quarter'd heaven, and found a name
> For every fix'd and every wand'ring star—
> The Pleiades, Hyades, and the Northern Car."

The same poet also describes Palinurus, the renowned pilot of the Trojan fleet, as watching the face of the nocturnal heavens.

> "Sidera cuncta notat tacito labentia cœlo,
> Arcturum, pluviasque Hyadas, geminosque Triones,
> Armatumque auro circumspicit Oriona."

> "Observe the stars, and notes their sliding course,
> The Pleiades, Hyades, and their wat'ry force;
> And both the Bears is careful to behold,
> And bright Orion, arm'd with burnished gold."

Indeed, this sagacious pilot was once so intent in gazing upon the stars while at the helm, that he fell overboard, and was lost to his companions.

> "Headlong he fell, and struggling in the main,
> Cried out for helping hands, but cried in vain."

66. *Alcyone*, of the 3d magnitude, being the brightest star in this cluster, is sometimes called the *light of the Pleiades.* The other five are principally of the 4th and 5th magnitudes. The Pleiades, or, as they are more familiarly termed, the *seven stars*, come to the meridian 10 minutes before 9 o'clock, on the evening of the 1st of January, and may serve in place of the sun, to indicate the time, and as a guide to the surrounding stars.

According to Hesiod, who wrote about 900 years before the birth of our Savior, the heliacal rising of the Pleiades took place on the 11th of May, about the time of harvest

> "When, Atlas-born, the Pleiad stars arise
> Before the sun above the dawning skies,
> 'Tis time to reap; and when they sink below
> The morn-illumined west, 'tis time to sow."

Thus, in all ages, have the stars been observed by the husbandman, for "signs and for seasons."

Pliny says that Thales, the Miletan astronomer, determined the cosmical setting of the Pleiades to be 25 days after the autumnal equinox. This would make a difference between the setting at that time and the present, of 35 days, and as a day answers to about 59′ of the ecliptic, these days will make 34° 25′. This divided by the annual precession (50¼″), will give 2465 years since the time of Thales. Thus does astronomy become the parent of chronology.

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65. Why Pleiades so called? Remark, and quotations from Virgil? 66. What said of *Alcyone?* Of the other five? When on the meridian? Serve what purpose? Period, and remark of Hesiod? Of Pliny? What calculation respecting the passage of the Pleiades over the meridian?

If it be borne in mind that the stars uniformly rise, come to the meridian, and set about four minutes earlier every succeeding night, it will be very easy to determine at what time the seven stars pass the meridian on any night subsequent or antecedent to the 1st of January. For example: at what time will the seven stars culminate on the 5th of January? Multiply the 5 days by 4, and take the result from the time they culminate on the 1st, and it will give 30 minutes after 8 o'clock in the evening.

67. The Pleiades are also sometimes called *Vergiliæ*, or the "Virgins of Spring;" because the sun enters this cluster in the "season of blossoms," about the 18th or May. He who made them alludes to this circumstance when he demands of Job: "Canst thou bind the sweet influences of the Pleiades," &c.—(Job 38 : 31.)

The Syrian name of the Pleiades is *Succoth*, or *Succoth-Benoth*, derived from a Chaldaic word, which signifies "to speculate, to observe," and the "Men of Succoth" (2 Kings 17: 30) have been thence considered observers of the stars.

68. The *Hyades* are situated 11° S. E. of the Pleiades, in the face of the Bull, and may be readily distinguished by means of five stars so placed as to form the letter V. (Map VIII., Fig. 29.) The most brilliant star is on the left, in the top of the letter, and called *Aldebaran;* from which the moon's distance is computed.

"A star of the first magnitude illumes
His radiant head; and of the second rank,
Another beams not far remote."

The ancient Greeks counted seven in this cluster:—

"The Bull's head shines with seven refulgent flames,
Which, *Grecia*, Hyades, from their *showering* names."

69. *Aldebaran* is of Arabic origin, and takes its name from two words which signify, "He went before, or led the way"—alluding to that period in the history of astronomy when this star led up the starry host from the vernal equinox. It comes to the meridian at 9 o'clock on the 10th of January, or 48½ minutes after Alcyone, on the 1st. When Aries is about 27° high, Aldebaran is just rising to the east. So MANILIUS:—

"Thus, when the *Ram* hath doubled ten degrees,
And join'd seven more, then rise the Hyades."

A line 15½° E. N. E. of Aldebaran will point out a bright star of the 2d magnitude in the extremity of the northern horn, marked Beta or El Nath; (this star is also in the foot of Auriga, and is common to both constellations.) From Beta in the northern horn, to Zeta, in the tip of the southern horn, it is 8°, in a southerly direction. This star forms a right angle with Aldebaran and Beta. Beta and Zeta, then, in the button of the horns, are in a line nearly north and south, 8° apart, with the brightest on the north. That very bright star 17½° N. of Beta, is *Capella*, in the constellation *Auriga*.

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67. What other name have the Pleiades, and why? Citation from Job? Syrian name? 68. Where are the *Hyades* situated? How known? Where the most brilliant star? Name? Are they shown on the map? 69. Origin and import of the name *Aldebaran?* When does it come to the meridian at 9 o'clock p.m.? Where is Beta? In what other constellation? Zeta, and its distance? How situated with reference to Aldebaran and Beta? How Beta and Zeta? Capella?

HISTORY.

According to the Grecian mythology, this is the animal which bore Europa over the seas to that country which derived from her its name. She was the daughter of Agenor and princess of Phœnicia. She was so beautiful that Jupiter became enamoured of her and assuming the shape of a snow-white bull, he mingled with the herds of Agenor, while Europa, with her female attendants, were gathering flowers in the meadows. Europa caressed the beautiful animal, and at last had the courage to sit upon his back. The god now took advantage of her situation, and with precipitate steps retired towards the shore, and crossed the sea with Europa upon his back, and arrived safe in Crete. Some suppose she lived about 1552 years before the Christian Era. It is probable, however, that this constellation had a place in the Zodiac before the Greeks began to cultivate a knowledge of the stars; and that it was rather an invention of the Egyptians or Chaldeans. Both the Egyptians and Persians worshipped a deity under this figure, by the name of Apis; and Belzoni is said to have found an embalmed bull in one of the notable sepulchres near Thebes.

In the Hebrew Zodiac, Taurus is ascribed to Joseph.

The Pleiades, according to fable, were the seven daughters of Atlas and the nymph Pleione, who were turned into stars, with their sisters the Hyades, on account of their amiable virtues and mutual affection.

Thus we everywhere find that the ancients, with all their barbarism and idolatry, entertained the belief that unblemished virtue and a meritorious life would meet their reward in the sky. Thus Virgil represents Magnus Apollo as bending from the sky to address the youth Iulus:—

> "Macte nova virtute puer; sic itur ad astra;
> Diis genite, et geniture Deos."

"Go on, spotless boy, in the paths of virtue; it is the way to the stars; offspring of the gods thyself—so shalt thou become the father of gods."

Our disgust at their superstitions may be in some measure mitigated, by seriously reflecting, that had some of these personages lived in our day, they had been ornaments in the Christian Church, and models of social virtue.

TELESCOPIC OBJECTS.

1. α Tauri (*Aldebaran*)—A star of the first magnitude with a telescopic companion; R. A. 4h. 26m. 44s.; Dec. N. 16° 10′ 9″. A 1, pale rose tint; B 12, sky blue.

2. β Tauri (*El Nath*)—R. A. 5h. 16m. 11s.; Dec. N. 28° 28′. A fine star, with a distant companion. A 2, brilliant white; B 10, pale grey.

3. γ Tauri—One of the Hyades; R. A. 4h. 10m. 41s.; Dec. 11° 14′ 1″. A bright star, with a distant telescopic companion; A 3½, yellow; B 11, pale blue.

4. η Tauri (*Alcyone*)—One of the Pleiades; R. A. 3h. 37m. 57s.; Dec. N. 23° 36′ 3″. A 3, greenish yellow; B, pale white and distant.

5. A nebulous star; R. A. 3h. 59m. 06s.; Dec. N. 30° 20′ 5″. A star of the eighth magnitude, with a faint luminous atmosphere surrounding it, and about 3′ in diameter. This star and nebula led Sir William Herschel to adopt his Nebula Theory, or theory of condensation of gas or nebulous matter, into suns and worlds.

6. A large nebula; R. A. 5h. 24m. 51s.; Dec. N. 21° 54′ 2″. It is about one degree north-west of ζ in the tip of the Bull's southern horn. It is an oval form, with several minute telescopic stars in its vicinity. For drawing, see Map VIII., Fig 30.

Of the *Pleiades* and *Hyades*, two prominent clusters, we have spoken at 64, 65.

ORION.—MAP III.

70. Whoever looks up to this constellation and learns its name, will never forget it. It is too beautifully splendid to need a description. When it is on the meridian, there is then above

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History.—Story of Europa and Jupiter? What probability? What said of the Egyptians and Persians? Hebrew zodiacs? Fabulous paternity of the Pleiades? Why turned into stars? What remarks respecting the ancients?

Telescopic Objects.—Alpha? Beta? Gamma? Eta? Nebulæ? Point out on the map.

70. What is said of Orion? Of the view when on the meridian? How is Orion repre-

the horizon the most magnificent view of the celestial bodies that the starry firmament affords; and it is visible to all the habitable world, because the equinoctial passes through the middle of the constellation. It is represented on celestial maps by the figure of a man in the attitude of assaulting the Bull, with a sword in his belt, a huge club in his right hand, and the skin of a lion in his left, to serve for a shield.

Manilius, a Latin poet, who composed five books on astronomy a short time before the birth of our Saviour, thus describes its appearance:—

"First next the Twins, see great *Orion* rise,
His arms extended stretch o'er half the skies;
His stride as large, and with a steady pace
He marches on, and measures a vast space;
On each broad shoulder a bright star display'd,
And three obliquely grace his hanging blade.
In his vast head, immers'd in boundless spheres,
Three stars, less bright, but yet as great, he bears,
But farther off removed, their splendor's lost;
Thus graced and arm'd he leads the starry host."

71. The centre of the constellation is midway between the poles of the heavens and directly over the equator. It is also about 8° W. of the solstitial colure, and comes to the meridian about the 23d of January. The whole number of visible stars in this constellation is 78; of which, two are of the first magnitude, four of the 2d, three of the 3d, and fifteen of the 4th.

72. Those four brilliant stars in the form of a long square or parallelogram, intersected in the middle by the "Three Stars," or "Ell and Yard," about 25° S. of the Bull's horns, form the outlines of Orion. The two upper stars in the parallelogram are about 15° N. of the two lower ones; and, being placed on each shoulder, may be called the epaulets of Orion. The brightest of the two lower ones is in the left foot, on the W., and the other which is the least brilliant of the four, in the right knee. To be more particular; Bellatrix is a star of the 2d magnitude on the W. shoulder; Betelguese is a star of the 1st magnitude, 7½° E. of Bellatrix, on the E. shoulder. It is brighter than Bellatrix, and lies a little farther toward the north; and comes to the meridian 30 minutes after it, on the 21st of January. These two form the upper end of the parallelogram.

73. *Rigel* is a splended star of the 1st magnitude, in the left foot, on the W. and 15° S. of Bellatrix. *Saiph* is a star of the 3d magnitude, in the right knee, 8½° E. of Rigel. These two form the lower end of the parallelogram.

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sented on the maps? How described by Manilius? 71. Situation of Orion? Number of visible stars? Magnitudes? 72. What is the *Ell and Yard?* What constitutes the outline of Orion? Where is *Bellatrix?* *Betelguese* and magnitude? 73. *Rigel?* *Saiph?*

——————"First in rank
The martial star upon his shoulder flames;
A rival star illuminates his foot;
And on his girdle beams a luminary
Which, in vicinity of other stars,
Might claim the proudest honors."

74. There is a little triangle of three small stars in the head of Orion, which forms a larger triangle with the two in his shoulders. In the middle of the parallelogram are three stars of the 2d magnitude, in the belt of Orion, that form a straight line about 3° in length from N. W. to S. E. They are usually distinguished by the name of the *Three Stars*, because there are no other stars in the heavens that exactly resemble them in position and brightness. They are sometimes denominated the *Three Kings*, because they point out the Hyades and Pleiades on one side, and Sirius, or the Dog-star, on the other. In Job they are called the *Bands of Orion;* while the ancient husbandmen called them *Jacob's rod*, and sometimes the *Rake.* The University of Leipsic, in 1807, gave them the name of *Napoleon.* But the more common appellation for them, including those in the sword, is the *Ell and Yard.* They derive the *latter* name from the circumstance that the line which unites the "three stars" in the belt measures just 3° in length, and is divided by the central star into two equal parts, like a yard-stick; thus serving as a graduated standard for measuring the distances of stars from each other. When, therefore, any star is described as being so many degrees from another, in order to determine the distance, it is recommended to apply this rule.

It is necessary that the scholar should task his ingenuity only a few evenings in applying such a standard to the stars, before he will learn to judge of their relative distances with an accuracy that will seldom vary a degree from the truth.

75. The northernmost star in the belt, called *Mintika*, is less than ½° S. of the equinoctial, and when on the meridian, is almost exactly over the equator. It is on the meridian, the 24th of January. The "three stars" are situated about 8° W. of the solstitial colure, and uniformly pass the meridian one hour and fifty minutes after the seven stars. There is a row of stars of the 4th and 5th magnitudes, S. of the belt, running down obliquely towards Saiph, which forms the sword. This row is also called the *Ell* because it is once and a quarter the length of the *Yard* or belt.

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74. What constitutes the *head* of Orion? What in the middle of the parallelogram? Names, and why? "Three stars?" "Three Kings?" "Bands of Orion," "Jacob's Rod," Napoleon," "Ell and Yard? Use of the Ell and Yard? 75. What said of *Mintika?* Of the "three stars?" What other row of stars? Forms what? Called what and why?

76. About 9° W. of Bellatrix, are eight stars, chiefly of the 4th magnitude, in a curved line running N. and S. with the concavity toward Orion; these point out the skin of the lion in his left hand. Of Orion, on the whole, we may remark with Eudosia:—

"He who admires not, to the stars is blind."

HISTORY.

According to some authorities, Orion was the son of Neptune and queen Euryale, a famous Amazonian huntress, and possessing the disposition of his mother, he became the greatest hunter in the world, and even boasted that there was not an animal on earth which he could not conquer. To punish this vanity, it is said that a scorpion sprung up out of the earth and bit his foot, that he died; and that at the request of Diana he was placed among the stars directly opposite to the Scorpion that caused his death. Others say that Orion had no mother, but was the gift of the gods, Jupiter, Neptune, and Mercury, to a peasant of Bœotia, as a reward of piety, and that he was invested with the power of walking over the sea without wetting his feet. In strength and stature he surpassed all other mortals. He was skilled in the working of iron, from which he fabricated a subterranean palace for Vulcan; he also walled in the coasts of Sicily against the inundations of the sea, and built thereon a temple to its gods.

Orion was betrothed to the daughter of Œnopion, but he, unwilling to give up his daughter, contrived to intoxicate the illustrious hero and put out his eyes, on the seashore where he had laid himself down to sleep. Orion, finding himself blind when he awoke, was conducted by the sound to a neighboring forge, where he placed one of the workmen on his back, and, by his directions, went to a place where the rising sun was seen with the greatest advantage. Here he turned his face toward the luminary, and, as it is reported, immediately recovered his sight, and hastened to punish the perfidious cruelty of Œnopion.

As the constellation Orion, which rises at noon about the 9th day of March, and sets at noon about the 21st of June, is generally supposed to be accompanied, at its rising, with great rains and storms, it became extremely terrible to mariners, in the early adventures of navigation. Virgil, Ovid, and Horace, with some of the Greek poets, make mention of this.

Thus Eneas accounts for the storm which cast him on the African coast on his way to Italy:—

"To that blest shore we steer'd our destined way,
When sudden, dire *Orion* rous'd the sea;
All charg'd with tempests rose the baleful star,
And on our navy pour'd his wat'ry war."

To induce him to delay his departure, Dido's sister advises her to

"Tell him, that, charged with deluges of rain,
Orion rages on the wintry main."

The name of this constellation is mentioned in the books of Job and Amos, and in Homer. The inspired prophet, penetrated like the psalmist of Israel with the omniscience and power displayed in the celestial glories, utters this sublime injunction: "Seek Him that maketh the seven stars and Orion, and turneth the shadow of death into morning." Job also, with profound veneration, adores his awful majesty who "commandeth the sun and sealeth up the stars; who alone spreadeth out the heavens, and maketh Arcturus, Orion, and Pleiades, and the chambers of the south:" and in another place, the Almighty demands of him—"Knowest thou the ordinances of heaven? Canst thou bind the sweet influences of the Pleiades, or loose the bands of Orion; canst thou bring forth Mazzaroth in his season, or canst thou guide Arcturus with his sons?"

Calmet supposes that *Mazzaroth* is here put for the whole order of celestial bodies in the Zodiac, which, by their appointed revolutions, produce the various seasons of the year, and the regular succession of day and night. *Arcturus* is the name of the principal star in Bootes, and is here put for the constellation itself. The expression, *his sons*, doubtless refers to Asterion and Chara, the two greyhounds, with which he seems to be pursuing the Great Bear around the North pole.

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76. What stars mentioned west of Bellatrix? Remark respecting Orion?

HISTORY.—Story of parentage? Disposition and boasting? Punishment? What other account? What mention of by Virgil? By Job and Homer? Supposition of Calmet? What meant by "Arcturus and his sons?"

TELESCOPIC OBJECTS.

1. *α* ORIONIS (*Betelguese*)—R. A. 5h. 46m. 30s.; Dec. N. 7° 22′ 3″. A 1, orange tint; B 11, bluish.

2. *β* ORIONIS (*Rigel*)—R. A. 5h. 6m. 51s; Dec. S. 8° 23′ 5″. A 1, pale yellow; B 9, sapphire blue. Map VIII. Fig. 3.

3. *γ* ORIONIS (*Bellatrix*)—R. A. 5h. 16m. 33s.; Dec. N. 6° 12′. A FINE STAR, with a minute distant companion. A 2, pale yellow; B 15, grey.

4. *δ* ORIONIS (*Mintaka*)—A coarse DOUBLE STAR in the girdle of the figure; R. A. 5h. 23m. 50s.; Dec. S. 0° 25′ 4″. A 2, white; B 7, pale violet.

5. *ε* ORIONIS (*Alnilam*) in the centre of his belt; R. A. 5h. 28m. 06s.; Dec. S. 1° 18′ 6″. A 2½, white and nebulous; B. 10, pale blue.

6. *ζ* ORIONIS (*Alnitah*) the last or lowest in the belt; R. A. 5h. 32m. 41s.; Dec. S. 2° 02′. A fine TRIPLE STAR. A 3, topaz yellow; B 6½, light purple; and C 10, gray.

7. A minute DOUBLE STAR and cluster, in Orion's left hand; R. A. 5h. 59m. 25s.; Dec. N. 13° 58′ 6″. A 7½, B 8½, both lucid white.

8. Another DOUBLE STAR in a cluster, in the left shoulder; R. A. 6h. 03m. 35s.; Dec. N. 5° 28′ 9″. A 9½ and B 10, both pale yellow. A tolerably rich cluster, with numerous stragglers.

9. A PLANETAY NEBULA, of a bluish white tint, on the nape of Orion's neck—small, pale, but quite distinct. R. A. 5h. 33m. 21s.; Dec. N. 9° 00′ 2″.

10. Two stars "in a WISPY NEBULA," just above the left hip; R. A. 5h. 38m. 33s.; Dec. N. 0° 00′ 7″. A 8½ and B. 9, both white. A singular mass, between two small stars, about equi-distant, in a blankish part of the heavens.

11. The GREAT NEBULA OF ORION—The most conspicuous nebula in all the heavens. It is situated in the *sword* of Orion, below the middle star of the belt; R. A. 5h. 27m. 25s.; Dec. S. 5° 30′. For its position in the constellation see Map VIII., Fig. 31. It may be seen with a common telescope. There is an apparent opening in one side of this nebula, through which, as through a window, we seem to get a glimpse of other heavens, and brighter regions. (Map VIII., Fig. 32.)

12. The middle star in the sword is in the midst of this nebula, and with powerful telescopes is found to be sextuple. The writer has often seen the fifth star with a 6-inch refractor. These stars constitute the *Trapezium of Orion*. The region around this nebula is rich in stars, as shown on Map VIII., Fig. 33.

LEPUS (THE HARE).—MAP III.

77. This constellation is situated directly south of Orion, and comes to the meridian at the same time; namely, on the 24th of January. It has a mean declination 18° S., and contains 19 small stars, of which, the four principal ones are of the 3d magnitude. It may be readily distinguished by means of four stars of the 3d magnitude, in the form of an irregular square, or trapezium.

78. *Zeta*, of the 4th magnitude, is the first star, and is situated in the back, 5° S. of Saiph, in Orion. About the same distance below Zeta are the four principal stars, in the legs and feet. These form the square. They are marked Alpha, Beta, Gamma, Delta.

TELESCOPIC OBJECTS.—Alpha? Beta? Gamma? Delta, &c.? What double stars? Nebulæ? Point out on the map?

77. Location of Lepus? Number and magnitude of stars? How may it be distinguished? 78. Size and situation of Zeta? Other principal stars? How marked on the map?

79. Alpha, otherwise called *Arneb*, and Beta form the N. W. end of the trapezium, and are about 3° apart. Gamma and Delta form the S. E. end, and are about $2\frac{1}{2}°$ apart. The upper right-hand one, which is Arneb, is the brightest of the four, and is near the centre of the constellation. Four or five degrees S. of Rigel are four very minute stars, in the ears of the Hare.

HISTORY.

This constellation is situated about 18° west of the Great Dog, which, from the motion of the earth, seems to be pursuing it, as the Greyhounds do the Bear, round the Circuit of the skies. It was one of those animals which Orion is said to have delighted in hunting, and which, for this reason, was made into a constellation and placed near him among the stars.

TELESCOPIC OBJECTS.

1. α Leporis (*Arneb*)—A distant double star; R. A. 5h. 25m. 40s.; Dec. S. 17° 56′ 05″. A 3½, pale yellow; B 9½, grey.

2. β Leporis (*Nihal*)—A star with a distant telescopic companion; R. A. 5h. 21m. 23s.; Dec. S. 20° 53′ 05″. A 4, deep yellow; B 11, blue.

3. γ Leporis—A wide triple star in a barren field; R. A. 5h. 37m. 48s.; Dec. S. 22° 30′ 02″. A 4, light yellow; B 6½, pale green; C 13, dusky.

4. ι Leporis—A delicate double star in the Hare's left ear; R. A. 5h. 04m. 50s.; Dec. S. 12° 03′ 09″. A 4½, white; B 12, pale violet, with a reddish distant star nearly north.

5. κ Leporis—A close double star, at the root of the left ear; R. A. 5h. 5m. 51s.; Dec. S. 13° 08′. A 5, pale white; B 9, clear grey.

6. A bright stellar nebula, under the Hare's feet; R. A. 5h. 17m. 50s.; Dec. S. 24° 39′ 09″. A fine object of a milky white tinge, and blazing towards the centre. Herschel describes it as "a beautiful cluster of stars, nearly 3′ in diameter, of a globular form, and extremly rich." An imaginary line run from Betelguese before α Leporis, and over β, will hit this object about 4° south-west of the latter.

COLUMBA (Noah's Dove).—MAP III.

80. This constellation is situated about 16° S. of the Hare, and is nearly on the same meridian with the "Three Stars," in the belt of Orion. It contains only 10 stars; one of the 2d, one of the 3d, and two of the 4th magnitudes; of these Phaet and Beta are the brightest, and are about $2\frac{1}{2}°$ apart. Phaet, the principal star, lies on the right, and is the highest of the two; Beta may be known by means of a smaller star just east of it, marked Gamma. A line drawn from the easternmost star in the belt of Orion, 32° directly south, will point out Phaet; it is also $11\frac{1}{2}°$ S. of the lower left-hand star in the square of the Hare, and makes with Sirius and Naos, in the ship, a large equilateral triangle.

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79. What other name has Alpha; and with Beta what does it form? What further description?

History.—Why was Lepus placed in the heavens?

Telescopic Objects.—Alpha? Beta? Gamma? Iota? Kappa? Nebula?

80. Situation of Columba? Number and size of stars? The two brightest, and situation? How find Phaet? What figure does it help to form? With what other stars?

HISTORY.

This constellation is so called in commemoration of the dove which Noah "sent forth to see if the waters were abated from off the face of the ground," after the ark had rested on mount Ararat. "And the dove came in to him in the evening, and lo, in her mouth was an olive leaf plucked off.

——————————"The surer messenger,
A dove sent forth once and again to spy
Green tree or ground, whereon his foot may light:
The second time returning in his bill
An olive leaf he brings, pacific sign!"

ERIDANUS (THE RIVER PO).—MAP III.

81. This constellation meanders over a large and very irregular space in the heavens. It is not easy, nor scarcely desirable, to trace out all its windings among the stars. Its entire length is not less than 130°; which, for the sake of a more easy reference, astronomers divide into two sections, the northern and the southern. That part of it which lies between Orion and the Whale, including the great bend about his paws, is distinguished by the name of the *Northern stream;* the remainder of it is called the *Southern stream.*

82. The Northern stream commences near Rigel, in the foot of Orion, and flows out westerly, in a serpentine course nearly 40° to the Whale, where it suddenly makes a complete circuit, and returns back nearly the same distance towards its source, but bending gradually down toward the south, when it again makes a similar circuit to the S. W., and finally disappears below the horizon.

West of Rigel there are five or six stars of the 3d and 4th magnitudes, arching up in a semi-circular form, and marking the *first* bend of the northern stream. About 8° below these, or 19° W. of Rigel, is a bright star of the 2d magnitude, in the *second* bend of the northern stream, marked *Gamma.* This star culminates 13 minutes after the Pleiades, and one hour and a quarter before Rigel. Passing Gamma, and a smaller star west of it, there are four stars nearly in a row, which bring us to the breast of Cetus. 8° N. of Gamma, is a small star named *Kied*, which is thought by some to be considerably nearer the earth than Sirius.

Theemim, in the southern stream, is a star of the 3d magnitude, about 17° S. W. of the square in Lepus, and may be known by means of a smaller star 1° above it. *Achernar* is a brilliant star of the 1st magnitude, in the extremity of the southern stream; but having 58° of S. declination, can never be seen in this latitude.

83. The whole number of stars in this constellation is 84; of which, one is of the 1st magnitude, one of the 2d, and eleven are of the 3d. Many of these cannot be pointed out by verbal description; they must be traced from the map.

HISTORY.—Origin of this constellation?

81. What said of Eridanus? Length? How divided? 82. Trace the Northern stream? Gamma? Theemim? Achernar? 83. Whole number of stars in Eridanus?

84. In the upper part of the Northern stream, near the feet of Taurus, may be seen a modern, but now discarded constellation, of which Captain Smyth says: "Abbé Hell (who also placed Herschel's Telescope among the celestials) has squeezed in his *Harpa Georgii*, to compliment a sovereign of those realms; having filched from Eridanus about thirty or forty stars, some of the 4th magnitude, for the purpose.

HISTORY.

Eridanus is the name of a celebrated river in Cisalpine Gaul, also called Padus. Its modern name is Po. Virgil calls it the king of rivers. The Latin poets have rendered it memorable from its connection with the fable of Phaeton, who, being a son of Phœbus and Clymene, became a favorite of Venus, who intrusted him with the care of one of her temples. This favor of the goddess made him vain, and he sought of his father a public and incontestable sign of his tenderness, that should convince the world of his origin. Phœbus, after some hesitation, made oath that he would grant him whatever he required, and no sooner was the oath uttered, than—

"The youth, transported, asks without delay,
To guide the sun's bright chariot for a day.
The god repented of the oath he took,
For anguish thrice his radiant head he shook;—
My son, says he, some other proof require,
Rash was my promise, rash was thy desire—
Not Jove himself, the ruler of the sky,
That hurls the three-forked thunder from above,
Dares try his strength; yet who as strong as Jove?
Besides, consider what impetuous force
Turns stars and planets in a different course.
I steer against their motions; nor am I
Borne back by all the current of the sky:
But how could you resist the orbs that roll
In adverse whirls, and stem the rapid pole?"

Phœbus represented the dangers to which he would be exposed in vain. He undertook the aërial journey, and the explicit directions of his father were forgotten. No sooner had Phaeton received the reins than he betrayed his ignorance of the manner of guiding the chariot. The flying coursers became sensible of the confusion of their driver, and immediately departed from the usual track. Phaeton repented too late of his rashness, and already heaven and earth were threatened with a universal conflagration as the consequence, when Jupiter, perceiving the disorder of the horses, struck the driver with a thunderbolt, and hurled him headlong from heaven into the river Eridanus. His body, consumed with fire, was found by the nymphs of the place, who honored him with a decent burial, and inscribed this epitaph upon his tomb:—

"*Hic situs est Phaeton, currus auriga paterni:*
Quene si non tenuit, magnis tamen excidit ausis."

His sisters mourned his unhappy end, and were changed by Jupiter into poplars.

"All the long night their mournful watch they keep,
And all the day stand round the tomb and weep."—OVID.

It is said the tears which they shed turned to amber, with which the Phœnicians and Carthaginians carried on in secrecy a most lucrative trade. The great heat produced on the occasion of the sun's departing out of his usual course, is said to have dried up the blood of the Ethiopians, and turned their skins black; and to have produced sterility and barrenness over the greater part of Libya.

"At once from life and from the chariot driven,
Th' ambitious boy fell thunderstruck from heaven."
* * * * * * *

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84. What discarded constellation mentioned? Is it on the map? Remark of Capt. Smyth?

HISTORY.—Named after what? Modern name? Fable of Phaeton? Its evident allusion?

"The breathless Phaeton, with flaming hair,
Shot from the chariot like a falling star,
That in a summer's evening from the top
Of heaven drops down, or seems at least to drop,
Till on the Po his blasted corpse was hurl'd,
Far from his country, in the western world."

The fable of Phaeton evidently alludes to some extraordinary heats which were experienced in a very remote period, and of which only this confused tradition has descended to later times.

TELESCOPIC OBJECTS.

1. β ERIDANI—A bright star with a distant telescopic companion, on the shin bone of Orion; R. A. 4h. 59m. 59s.; Dec. S. 5° 17′ 9″. A 3, topaz yellow; B 12, pale blue. This star is just above Rigel, in the direction of the Hyades.

2. γ ERIDANI—A star with a distant companion; R. A. 3h. 50m. 34s.; Dec. S. 13° 58′. A 2½, yellow; B 10 pale grey.

3. A MILK WHITE NEBULA; R. A. 3h. 33m. 02s.; Dec. S. 19° 04′ 8″. Pale, distinct, round, and bright in the centre.

4. A PLANETARY NEBULA; R. A. 4h. 06m. 50s.; Dec. S. 13° 09′ 1″. About 4½° from γ in the direction of Rigel. A splendid though not very conspicuous object, of a greyish white color. Map VIII., Fig. 34, represents it in its best aspects, highly magnified, with four telescopic stars in the field, two of which point exactly towards the nebula.

SCEPTRUM BRANDENBURGIUM (SCEPTRE OF BRANDENBURG). MAP III.

85. This is a slender constellation, situated between the two streams of the River Po. It was constructed by Kirch, in 1688, and recognized by Bode a century afterwards; but is now generally discarded, though retained on the map. It is composed of four stars of the 3d, 4th and 5th magnitudes, running north and south; and is usually included in Eridanus.

AURIGA (THE CHARIOTEER).—MAP III.

86. The Charioteer, called also the Wagoner, is represented on the celestial map by the figure of a man in a reclining posture, resting one foot upon the horn of Taurus, with a goat and her kids in his left hand, and a bridle in his right.

It is situated N. of Taurus and Orion, between Perseus on the W. and the Lynx on the E. Its mean declination is 45° N.; so that when on the meridian, it is almost directly overhead in New England. It is on the same meridian with Orion, and culminates at the same hour of the night. Both of these constellations are on the meridian at 9 o'clock on the 24th of

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TELESCOPIC OBJECTS.—Beta? Gamma? Nebula? Point out on the map.

85. Describe the Sceptre of Brandenburgh? Situation? When and by whom constituted? Is it recognized by astronomers? Number and magnitude of stars? 86. How is Auriga represented? Situation? When on the meridian?

January, and 1 hour and 40 minutes east of it on the 1st of January.

87. The whole number of visible stars in Auriga, is 66, including one of the 1st and one of the 2d magnitude, which mark the shoulders. *Capella* is the principal star in this constellation, and is one of the most brilliant in the heavens. It takes its name from Capella, the goat, which hangs upon the left shoulder. It is situated in the west shoulder of Auriga, 24° E. of Algol, and 28° N. E. of the Pleiades. It may be known by a little sharp-pointed triangle formed by three stars, 3° or 4° this side of it, on the left. It is also 18° N. of El Nath, which is common to the northern horn of Taurus, and the right foot of Auriga. Capella comes to the meridian on the 19th of January, just 2½ minutes before Rigel, in the foot of Orion, which it very much resembles in brightness.

Menkalina, in the east shoulder, is a star of the 2d magnitude, 7½° E. of Capella, and culminates the next minute after Betelguese, 37⅔° S. of it. *Theta*, in the right arm, is a star of the 4th magnitude, 8° directly south of Menkalina.

It may be remarked as a curious coincidence, that the two stars in the shoulders of Auriga are of the same magnitude, and just as far apart as those in Orion, and opposite to them. Again, the two stars in the shoulders of Auriga, with the two in the shoulders of Orion, mark the extremities of a long, narrow parallelogram, lying N. and S., and whose length is just five times its breadth. Also, the two stars in Auriga, and the two in Orion, make two slender and similar triangles, both meeting in a common point, half way between them at El Nath, in the northern horn of Taurus.

Delta, a star of the 4th magnitude in the head of Auriga, is about 9° N. of the two in the shoulders, with which it makes a triangle, about half the height of those just alluded to, with the vertex at Delta. The two stars in the shoulders are therefore the base of two similar triangles, one extending about 9° N. to the head, the other 18° S. to the heel, on the top of the horn: both figures together resembling an elongated diamond.

Delta in the head, Menkalina in the right shoulder, and Theta in the arm of Auriga, make a straight line with Betelguese in Orion, Delta in the square of the Hare, and Beta in Noah's Dove; all being very nearly on the same meridian, 48 W. of the solstitial colure.

> "See next the Goatherd with his kids; he shines
> With seventy stars, deducting only four,
> Of which Capella never sets to us.
> And scarce a star with equal radiance beams
> Upon the earth: two other stars are seen
> Due to the second order."—*Eudosia.*

HISTORY.

The Greeks give various accounts of this constellation; some supposed it to be Erichthonius, the fourth king of Athens, and son of Vulcan and Minerva, who awarded him a place among the constellations on account of his many useful inventions. He was of a monstrous shape. He is said to have invented chariots, and to have excelled all others in the management of horses. In allusion to this, Virgil has the following lines:—

> "Primus Erichthonius currus et quatuor ausus
> Jungere equos, rapidisque rotis insistere victor."
> Georgic. Lib. iii. p. 113.

> "Bold Erichthonius was the first who join'd
> Four horses for the rapid race design'd,
> And o'er the dusty wheels presiding sat."—*Dryden.*

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87. Number of stars visible? Magnitude and situation of Capella? How known? Menkalina? Delta compared with Theta?

HISTORY.—The first supposition? Second? Third? Opinion of Jamieson?

Other writers say that Bootes invented the chariot, and that Auriga was the son of Mercury, and charioteer to Œnomaus, king of Pisa, and so experienced, that he rendered his horses the swiftest in all Greece. But as neither of these fables seems to account for the goat and her kids, it has been supposed that they refer to Amalthæa and her sister Melissa, who fed Jupiter, during his infancy, with goat's milk, and that, as a reward for their kindness, they were placed in the heavens. But there is no reason assigned for their being placed in the arms of Auriga, and the inference is unavoidable, that mythology is at fault on this point.

Jamieson is of opinion that Auriga is a mere type or scientific symbol of the beautiful fable of Phaeton, because he was the attendant of Phœbus at that remote period when Taurus opened the year.

TELESCOPIC OBJECTS.

1. *α* Aurigæ (*Capella*)—A fine star with two distant companions, on the right shoulder-blade of Auriga; R. A. 5h. 04m. 53s.; Dec. N. 45° 49′ 07″. A 1, bright white; B 12, pale blue; C 9, grey.

2. *β* Aurigæ (*Menkalina*)—A bright star in the left shoulder, with a distant companion; R. A. 5h. 47m. 48s.; Dec. N. 44° 55′ 3″. A 2, yellow; B 10½, bluish.

3. A rich cluster of minute stars, on the left thigh; R. A. 5h. 18m. 41s.; Dec. N. 35° 44′ 9″ A singular figure, somewhat like a cross. Find by a line from Rigel, northwards through *β* Tauri, and about 7° beyond.

4. A resolvable nebula; R. A. 5h. 20m. 51s.; Dec. N. 34° 06′ 9″. Situated in a rich field of minute stars.

CAMELOPARDALUS (the camelopard).—MAP VI.

88. This constellation was made by Hevelius out of the unformed stars which lay scattered between Perseus, Auriga, the head of Ursa Major, and the Pole star. It is situated directly N. of Auriga and the head of the Lynx, and occupies nearly all the space between these and the pole. It contains 58 small stars; the five largest of which are only of the 4th magnitude.

89. The principal star lies in the thigh, and is about 20° from Capella, in a northerly direction. It marks the northern boundary of the temperate zone; being less than one degree S. of the Arctic circle. There are two other stars of the 4th magnitude, near the right knee, 12° N. E. of the first mentioned. They may be known by their standing 1° apart and alone.

The other stars in this constellation are too small, and too much scattered to invite observation.

HISTORY.

The Camelopard is so called from an animal of that name, peculiar to Ethiopia. This animal resembles both the camel and the leopard. Its body is spotted like that of the leopard. Its neck is about seven feet long, its fore and hind legs from the hoof to the second joint, are nearly of the same length; but from the second joint of the legs to the body, the fore legs are so long in comparison with the hind ones, that no person could sit upon its back without instantly sliding off, as from a horse that stood up on his hind feet.

Telescopic Objects.—Alpha? Beta? Cluster? Nebulæ?
88. Origin of Camelopardalus? Situation and extent? Number and size of its stars?
89. Where is its principal star? The next two? How known?
History.—Any mythological story? What said of the animal?

TELESCOPIC OBJECTS.

1. α CAMELOPARDALI—A neat DOUBLE STAR between the hind feet of the animal, half way between α Persei and δ in the head of Auriga; R. A. 4h. 19m. 23s.; Dec. N. 53° 33 3″ A 7½, white; B 8½, sapphire blue.

2. Another close DOUBLE STAR, between the hind feet; R. A. 4h. 27m. 18s.; Dec. N. 53° 09′. A 5½, yellow; B. 7½, pale blue.

3. A very delicate DOUBLE STAR in the animal's hind hoof; R. A. 4h. 44m. 28s.; Dec. N 53° 29′ 3″. A 5, white; B 13, orange.

4. A fine DOUBLE STAR in the lower part of the back of the neck; R. A. 4h. 46m. 19s. Dec. N. 79° 01′ 8″. A 5½, light yellow; B 9, pale blue.

5. A bright PLANETARY NEBULA, of a bluish white tint, about 60″ in diameter, in the hind flank of the animal, R. A. 4h. 53m. 29s. Dec. N. 60° 23′ 5″. A curious body, in a rich field of small stars.

CHAPTER IV.

CONSTELLATIONS ON THE MERIDIAN IN FEBRUARY.

THE LYNX.—MAPS III. AND VI.

90. THIS constellation, like that of the Camelopard, exhibits no very interesting features by which it can be distinguished. It contains only a moderate number of inferior stars, scattered over a large space N. of Gemini, and between Auriga and Ursa Major.

91. The whole number of stars in this constellation is 44, including only three that are so large as the 3d magnitude. The largest of these, near the mouth, is in the solstitial colure, 14½° N. of Menkalina, in the E. shoulder of Auriga. The other two principal stars are in the brush of the tail, 3½° S. W. of another star of the same brightness in the mouth of the Lesser Lion, with which it makes a small triangle. Its centre is on the meridian at 9 o'clock on the 23d, or at half-past 7 on the 1st of February.

TELESCOPIC OBJECTS.

1. A close DOUBLE STAR, in the nose of the Lynx; R. A. 6h. 07m. 51s.; Dec. N. 59° 25′ 8″ About 30° from the Pole star, on a line toward Sirius. A 6, and B 7½, both white. An elegant but difficult object.

2. A close DOUBLE STAR in the eye of the Lynx, between Dubhi and Capella; R. A. 6h 38m. 57s.; Dec. N. 59° 37′ 6″. A 5½, golden yellow; B 7, purple. A delicate and pretty object.

3. A coarse TRIPLE STAR on the animal's lower jaw; R. A. 6h. 12m. 50s.; Dec. N. 58° 29′ 7″. A. 6, orange tinge; B 13, blue; and C 9, pale garnet.

4. A ROUND NEBULA, in the Lynx, or fore paws of Leo Minor; R. A. 9h. 14m. 32s. Dec. N. 35° 11′ 9″. It is pale white, sparkling in the centre.

TELESCOPIC OBJECTS.—Alpha? What other double stars? Nebula?

90. Describe the Lynx? Situation? 91. Number and size of its stars? Where is the largest situated? The other two principal stars?

TELESCOPIC OBJECTS.—What double stars? Triple? Nebula

TELESCOPIUM HERSCHELLII (HERSCHEL'S TELESCOPE).—MAP III.

92. About midway between the body of the Lynx and Gemini, may be seen the rude figure of a refracting Telescope, with its stand. It was made out of a few unformed stars, by Abbé Hell, in honor of Sir William Herschel, but is now generally discarded. It is retained on the map more as a matter of history than to perpetuate it as a constellation.

GEMINI (THE TWINS).—MAP III.

93. This constellation represents, in a sitting posture, the twin brothers, Castor and Pollux. It is the *third sign*, but *fourth constellation* in the order of the Zodiac, and is situated south of the Lynx, between Cancer on the east, and Taurus on the west.

94. The plane of the Ecliptic passes through the centre of Gemini; and as the earth moves round in her orbit from the first point of Aries to the same point again, the sun, in the meantime, will *appear* to move through the *opposite* signs, or those which are situated right over against the earth, on the other side of her orbit. Accordingly, if we could *see* the stars as the sun appeared to move by them, we should see it passing over the constellation Gemini between the 21st of June and the 23d of July; but we seldom see more than a small part of any constellation through which the sun is then passing, because the feeble lustre of the stars is obscured by the superior effulgence of the sun.

When the sun is just entering the outlines of a constellation eastward, its eastern limit may be seen in the evening twilight, just above the setting sun. So when the sun has arrived at the eastern limit of a constellation, the western part of it may be seen rising in the morning twilight, just before the rising sun. Under other circumstances, when the sun is said to be in, or to enter, a particular constellation, it is to be understood that that constellation is not then visible, but that those opposite to it are. For example: whatever constellation sets with the sun on any day, it is plain that the one opposite to it must be then rising, and continue visible through the night. Also, whatever constellation rises and sets with the sun to-day, will, six months hence, rise at sun-setting, and set at sun-rising. For example: the sun is in the centre of Gemini about the 6th of July, and must rise and set with it on that day; consequently, six months from that time, or about the 4th of January, it will rise in the east, just when the sun is setting in the west, and will come to the meridian at midnight; being then exactly opposite the sun. And as the stars gain upon the sun at the rate of two hours every month, it follows that the centre of this constellation will, on the 17th of February, come to the meridian three hours earlier, or at 9 o'clock in the evening.

The sun is in the vernal equinox about the 21st of March, from whence it advances

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92. What said of Herschel's Telescope? Why perpetuated on the map? 93. How is Gemini represented? Its order in the signs, &c.? Situation? 94. How with respect to the Ecliptic? What result from this fact? What remarks respecting the sun and constellations?

through one sign or constellation every succeeding month thereafter; and that each *constellation* is one month in advance of the *sign* of that name: wherefore, reckon Pisces in March, Aries in April, Taurus in May, and Gemini in June, &c., beginning with each constellation at the 21st, or 22d of the month.

95. Gemini contains 85 stars, including two of the 2d, three of the 3d, and six of the 4th magnitudes. It is readily recognized by means of the two principal stars, *Castor* and *Pollux*, of the 1st and 2d magnitudes, in the heads of the Twins, about $4\frac{1}{2}°$ apart.

There being only 11 minutes' difference in the transit of these two stars over the meridian, they may both be considered as culminating at 9 o'clock about the 24th of February. *Castor*, in the head of Castor, is a star of the 1st magnitude, 4½° N. W. of Pollux, and is the northernmost and the brightest of the two. *Pollux* is a star of the 2d magnitude, in the head of Pollux, and is 4½° S. E. of Castor. This is one of the stars from which the moon's distance is calculated in the Nautical Almanac.

——"Of the famed Ledean pair,
One most illustrious star adorns their sign,
And of the second order shine twin lights."

96. The relative magnitude or brightness of these stars has undergone considerable changes at different periods; whence it has been conjectured by various astronomers that Pollux must vary from the 1st to the 3d magnitude. But Herschel, who observed these stars for a period of 25 years, ascribes the variation to Castor, which he found to consist of two stars, very close together, the less revolving about the larger once in 342 years and two months.

Bradley and Maskelyne found that the line joining the two stars which form Castor was, at all times of the year, parallel to the line joining Castor and Pollux; and that both of the former move around a common centre between them, in orbits nearly circular, as two balls attached to a rod would do, if suspended by a string affixed to the centre of gravity between them.

"These men," says Dr. Bowditch, "were endowed with a sharpness of vision, and a power of penetrating into space, almost unexampled in the history of astronomy."

97. About 20° S. W. of Castor and Pollux, and in a line nearly parallel with them, is a row of stars 3° or 4° apart, chiefly of the 3d and 4th magnitudes, which distinguish the feet of the Twins. The brightest of these is *Alhena*, in Pollux's upper foot; the next small star S. of it, is in his other foot; the two upper stars in the line next above Gamma, mark Castor's feet.

This row of feet is nearly two-thirds of the distance from Pollux to Betelguese in Orion, and a line connecting them will pass through Alhena, the principal star in the feet. About two thirds of the distance from the two in the head to those in the feet, and nearly parallel with them, there is another row of three stars about 6° apart, which mark the knees.

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95. Number of stars in Gemini? Magnitudes? How recognize this constellation? What said of the culmination of Castor, and of Pollux? 96. Are they variable? What did Bradley and Maskelyne ascertain? Remark of Bowditch? 97. What constitute the *feet* of Gemini? Alhena? How situated? What mark the *knees?*

98. There are, in this constellation, two other remarkable parallel rows, lying at right angles with the former ; one, leading from the head to the foot of Castor, the brightest star being in the middle, and in the knee : the other, leading from the head to the foot of Pollux, the brightest star, called Wasat, being in the body, and Zeta, next below it, in the knee.

Wasat is in the ecliptic, and very near the center of the constellation. The two stars, Mu and Tejat, in the northern foot, are also very near the ecliptic; Tejat is a small star of between the 4th and 5th magnitudes, 2° W. of Mu, and deserves to be noticed because it marks the spot of the summer solstice, in the tropic of Cancer, just where the sun is on the longest day of the year, and is, moreover, the dividing limit between the torrid and the N. temperate zone.

Propus, also in the ecliptic, 2½° W. of Tejat, is a star of only the 5th magnitude, but rendered memorable as being the star which served for many years to determine the position of the planet Herschel, after its first discovery.

HISTORY.

Castor and Pollux were twin brothers, sons of Jupiter, by Leda, the wife of Tyndarus, king of Sparta. The manner of their birth was very singular. They were educated at Pallena, and afterwards embarked with Jason in the celebrated contest for the golden fleece, at Colchis; on which occasion they behaved with unparalleled courage and bravery. Pollux distinguished himself by his achievements in arms and personal prowess, and Castor in equestrian exercises and the management of horses; whence they are represented, in the temples of Greece, on white horses, armed with spears, riding side by side, their heads crowned with a *petasus*, on whose top glitters a star. Among the ancients, and especially among the Romans, there prevailed a superstition that Castor and Pollux often appeared at the head of their armies, and led on their troops to battle and to victory.

"Castor and Pollux, first in martial force,
One bold on foot, and one renown'd for horse.

Fair Leda's twins in time to stars decreed,
One fought on foot, one curb'd the fiery steed."—*Virgil.*

"Castor alert to tame the foaming steed,
And Pollux strong to deal the manly deed."—*Martial.*

The brothers cleared the Hellespont and the neighboring seas from pirates after their return from Colchis; from which circumstance they have ever since been regarded as the friends and protectors of navigation. In the Argonautic expedition during a violent storm, it is said two flames of fire were seen to play around their heads, and immediately the tempest ceased, and the sea was calm. From this circumstance, the sailors inferred, that whenever both fires appeared in the sky, it would be fair weather; but when only one appeared, there would be storms.

St. Paul, after being wrecked on the island of Melita, embarked for Rome "in a ship whose sign was *Castor* and *Pollux*;" so formed, no doubt, in accordance with the popular belief that these divinities presided over the science and safety of navigation.

They were initiated into the sacred mysteries of Cabiri, and into those of Ceres at Eleusis. They were invited to a feast at which Lynceus and Idas were going to celebrate their nuptials with Phœbe and Telaria, the daughters of Leucippus, brother to Tyndarus. They became enamored of the daughters, who were about to be married, and resolved to supplant their rivals: a battle ensued, in which Castor killed Lynceus, and was himself killed by Idas. Pollux revenged the death of his brother by killing Idas; but being himself *immortal* and most tenderly attached to his deceased brother, he was unwilling to survive him; he therefore entreated Jupiter to restore him to life, or to be deprived himself of immortality; wherefore, Jupiter permitted Castor, who had been slain, to share the immortality of Pollux; and consequently as long as the one was upon earth, so long was the other detained in the infernal regions, and they alternately lived and died every day. Jupiter also further rewarded their fraternal attachment by changing them both

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98. What other remarkable rows of stars in Gemini? Situation of *Wasat?* Of *Tejat?* Of *Propus?*

HISTORY.—Myth of the parentage of Gemini? Their achievements? Roman superstition? That of sailors? Allusion of St. Paul? Story of the fatal wedding?

into a constellation under the name of *Gemini*, *Twins*, which, it is strangely pretended, never appear together, but when one rises the other sets, and so on, alternately.

> "By turns they visit this ethereal sky,
> And live alternate, and alternate die."—*Homer.*

> "Pollux, offering his alternate life,
> Could free his brother, and could daily go
> By turns aloft, by turns descend below."—*Virgil.*

Castor and Pollux were worshiped both by the Greeks and Romans, who sacrificed white lambs upon their altars. In the Hebrew Zodiac, the constellation of the Twins refers to the tribe of Benjamin.

TELESCOPIC OBJECTS.

1. α Geminorum (*Castor*)—A neat double star; R. A. 7h. 24m. 23s.; Dec. N. 32° 14′. A 3. bright white; B 3½, pale white; with a third star of the 11th magnitude about 72″ distant. A Binary System, with a probable period of 232 years. A beautiful object, and easily found. Map VIII., Fig. 4.

2. β Geminorum—A quadruple star in the eye of Pollux, R. A. 7h. 35m. 31s.; Dec. N. 28° 25′ 4″. A 2, orange tinge; B 12, ash-colored; C 11, pale violet, with another minute companion visible with the best instruments.

3. γ Geminorum (*Alhena*)—A coarse triple star, in the right foot of Pollux; R. A. 6h. 28m. 28s.; Dec. N. 16° 31′ 8″.; A 3, brilliant white; B 13, and C 12, both pale plum color. It is on a line from Rigel to β Geminorum, and nearest the former.

4. δ Geminorum (*Wasat*)—A double star on the right hip of Pollux; R. A. 7h. 10m. 34s.; Dec. N. 22° 16′ 3″. A 3½, pale white; B 9, purple.

5. ε Geminorum (*Melucta*)—A star with a distant companion, on Castor's right knee; R. A. 6h. 34m. 05s.; Dec. N. 25° 16′ 9″. A 3, white; B 9½, cerulean blue.

6. ζ Geminorum—A coarse triple star on the right knee of Pollux; R. A. 6h. 54m. 37s.; Dec. N. 20° 47′ 9″. A 4, pale topaz; B 8, violet; C 13, grey.

7. A cluster, near the right foot of Castor; R. A. 5h. 59m. 01s.; Dec. N. 24° 21′ 3″. A gorgeous field of stars from the 9th to the 16th magnitudes.

8. A cluster in the calf of Pollux's right leg; R. A. 6h. 45m. 56s.; Dec. N. 18° 10′ 5″. A faint angular group of extremely small stars, in a rich region, but seen with difficulty. See Map VIII., Fig. 35.

9. A compressed cluster under the left shoulder of Pollux; one-third the distance from β Geminorum, to β Canis Minoris; R. A. 7h. 28m. 57s.; Dec. N. 21° 55′ 7″. A faint object about 12 in diameter, with a small star near the centre. Map VIII., Fig. 36.

CANIS MINOR (THE LITTLE DOG).—MAP III.

99. This small constellation is situated about 5° N. of the equinoctial, and midway between Canis Major and the Twins. It contains 14 stars, of which two are very brilliant. The brightest star is called *Procyon.* It is of the 1st magnitude, and is about 4° S. E. of the next brightest, marked *Gomelza*, which is of the 3d magnitude. These two stars resemble the two in the head of the Twins. Procyon, in the Little Dog, is 23° S. of Pollux in Gemini, and Gomelza is about the same distance S. of Castor.

100. A great number of geometrical figures may be formed of the principal stars in the vicinity of the Little Dog. For example: Procyon is 23° S. of Pollux, and 26° E. of Betel-

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Telescopic Objects.—Alpha? Beta? Gamma? Delta, &c.? Clusters? Which shown on the map?

99. Where is Canis Minor situated? Number of stars? Name of brightest? Magnitude? Next brightest? What do these two resemble? 100. What said of geometrical figures? Of the name *Procyon?* Its import?

guese, and forms with them a large right-angled triangle. Again, Procyon is equi-distant from Betelguese and Sirius, and forms with them an equilateral triangle whose sides are each about 26°. If a straight line, connecting Procyon and Sirius, be produced 23° farther, it will point out Phaet, in the Dove.

Procyon is often taken for the name of the Little Dog, or for the whole constellation, as Sirius is for the greater one; hence it is common to refer to either of these constellations by the name of its principal star. Procyon comes to the meridian 53 minutes *after* Sirius, on the 24th of February; although it rises, in this latitude, about half an hour *before* it. For this reason, it was called *Procyon*, from two Greek words which signify (*Ante Canis*) "before the dog."

HISTORY.

The Little Dog, according to Greek fable, is one of Orion's hounds. Some suppose it refers to the Egyptian god Anubis, which was represented with a dog's head; others to Diana, the goddess of hunting; and others, that it is the faithful dog Mæra, which belonged to Icarus, and discovered to his daughter Erigone the place of his burial. Others, again, say it is one of Actæon's hounds that devoured their master, after Diana had transformed him into a stag, to prevent, as she said, his betraying her.

"This said, the man began to disappear
By slow degrees, and ended in a deer.
Transform'd at length, he flies away in haste,
And wonders why he flies so fast
But as by chance, within a neighb'ring brook,
He saw his branching horns, and alter'd look,
Wretched Acteon! in a doleful tone
He tried to speak, but only gave a groan;
And as he wept, within the watery glass,
He saw the big round drops, with silent pace,
Run trickling down a savage, hairy face.
What should he do? or seek his old abodes,
Or herd among the deer, and skulk in woods?
As he thus ponders, he behind him spies
His opening hounds, and now he hears their cries.
From shouting men, and horns, and dogs he flies.
When now the fleetest of the pack that press'd
Close at his heels, and sprung before the rest,
Had fastened on him, straight another pair
Hung on his wounded side, and held him there,
Till all the pack came up, and every hound
Tore the sad huntsman groveling on the ground."

It is not difficult to deduce the moral of this fable. The selfishness and caprice of human friendship furnish daily illustrations of it. While the good man, the philanthropist, or the public benefactor, is in affluent circumstances, and, with a heart to devise, has the power to minister blessings to his numerous beneficiaries, his virtues are the general theme; but when adverse storms have changed the ability, though they could not shake the will of their benefactor, he is straightway pursued, like Actæon, by his own hounds; and, like Actæon, he is "torn to the ground" by the fangs that fed upon his bounty.

It is most probable, however, that the Egyptians were the inventors of this constellation; and as it always rises a little before the Dog Star, which, at a particular season, they so much dreaded, it is properly represented as a little watchful creature, giving notice like a faithful sentinel of the other's approach.

TELESCOPIC OBJECTS.

1. α Canis Minoris (*Procyon*)—A bright star in the loins of the dog with a distan ompanion; R. A. 7h. 30m. 55s; Dec. N. 5° 37′ 8″. A 1½, yellowish white; B 8, orange int. Several small stars in the field.

History.—What is the Little Dog supposed to represent? Fable of Actæon? Its moral? Who probably invented this constellation? To represent what?

Telescopic Objects.—Alpha? Beta? Double star? Triple?

2. β Canis Minoris (*Gomelza*)—A wide triple star in theneck; R. A. 7h. 18m. 28s.; Dec. N. 8° 36′ 4″. A 3, white; B 12, orange; C 10, flushed—the last coarsely double with one of the same magnitude. Other stars in the field.

3. A close double star, in a fine vicinity in the loins; R. A. 7h. 31m. 37s.; Dec. N. 5° 35′ 7″. A 7, white; B 8, ash-colored, with a minute blue star 2′ distant.

4. A wide triple star, 6° S. E. of Procyon; R. A. 7h. 50m. 03s.; Dec. N. 2° 38′ 8″. A 6, pale white; B 8, bluish; C 9, blue.

MONOCEROS (the unicorn).—MAP III.

101. This is a modern constellation, made out of the unformed stars of the ancients that lay scattered over a large space of the heavens between the two Dogs. It extends a considerable distance on each side of the equinoctial, and its centre is on the same meridian with Procyon.

102. It contains 31 small stars, of which the seven principal ones are of only the 4th magnitude. Three of these are situated in the head, 3° or 4° apart, forming a straight line N. E. and S. W. about 9° E. of Betelguese in Orion's shoulder, and about the same distance S. of Albena in the foot of the twins.

The remaining stars in this constellation are scattered over a large space, and being very small, are unworthy of particular notice.

HISTORY.

The Monoceros is a species of the Unicorn or Rhinoceros. It is about the size of a horse, with one white horn growing out of the middle of its forehead. It is said to exist in the wilds of Ethiopia, and to be very formidable.

Naturalists say that, when pursued by the hunters, it precipitates itself from the tops of the highest rocks, and pitches upon its horn, which sustains the whole force of its fall, so that it receives no damage thereby. Sparmann informs us, that the figure of the unicorn, described by some of the ancients, has been found delineated on the surface of a rock in Caffraria; and thence conjectures that such an animal, instead of being *fabulous*, as some suppose, did once actually exist in Africa. Lobo affirms that he has seen it.

The *rhinoceros*, which is akin to it, is found in Bengal, Siam, Cochin China, part of China Proper, and the isles of Java and Sumatra.

TELESCOPIC OBJECTS.

1. A most delicate double star (*f*), in the Unicorn's eye; R. A. 6h. 26m. 06s.; Dec. N. 7° 41′ 05″. A 6, yellowish white: B 16, dusky. A difficult object.

2. A neat double star (*b*), in the nostril, 7½° east of *Betelguese*; R. A. 6h. 15m. 17s.; Dec. N. 4° 40′ 01″. A 5½, golden yellow; B 8, lilac.

3. A fine triple star in the right fore-leg; R. A. 6h. 21m. 04s.; Dec. S. 6° 56′ 01″. A 6½, white; B 7, and C 8, both pale white. A ray shot from the Bull's eye through Bellatrix, and rather more than as far again, will pick it up. Supposed by Herschel to be a *triple system*, periods A B 17,000 ys. B C 1000. Shown double only on the map of the constellations. Telescopic view, Map VIII., Fig. 5.

4. A delicate triple star, in a magnificent stellar field, between the Unicorn's ears; R. A. 6h. 32m. 10s.; Dec. N. 10° 02′ 02″. One-third the distance from *Procyon* to *Aldebaran*. A 6, greenish; B 9½, pale grey; C 15, blue. A fine object.

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101. Character and situation of Monoceros? Extent? 102. Number and size of its stars? How three of the largest situated?

History.—What said of the animal itself? Is it not wholly fabulous?

Telescopic Objects.—Double stars? Triple? Any shown on the map?

CANIS MAJOR (THE GREAT DOG).—MAP III.

103. This interesting constellation is situated southward and eastward of Orion, and is universally known by the brilliance of its principal star, *Sirius*, which is apparently the largest and brightest in the heavens. It glows in the winter hemisphere with a lustre which is unequaled by any other star in the firmament. Its distance from the earth, though computed at 20 millions of millions of miles, is supposed to be less than that of any other star: a distance, however, so great that a cannon ball, which flies at the rate of 19 miles a minute, would be two millions of years in passing over the mighty interval; while sound, moving at the rate of 13 miles a minute, would reach Sirius in little less than three millions of years.

It may be shown in the same manner, that a ray of light, which occupies only 8 minutes and 13 seconds in coming to us from the sun, which is at the rate of nearly two hundred thousand miles a second, would be 3 years and 82 days in passing through the vast space that lies between Sirius and the earth. Consequently, were it blotted from the heavens, its light would continue visible to us for a period of 3 years and 82 days after it had ceased to be.

If the *nearest* stars give such astonishing results, what shall we say of those which are situated a thousand times as far *beyond* these, as these are from us?

104. In the remote ages of the world, when every man was his own astronomer, the rising and setting of Sirius, or the *Dog Star*, as it is called, was watched with deep and various solicitude. The ancient Thebans, who first cultivated astronomy in Egypt, determined the length of the year by the number of its risings. The Egyptians watched its rising with mingled apprehensions of hope and fear; as it was ominous to them of agricultural prosperity or blighting drought. It foretold to them the rising of the Nile, which they called *Siris*, and admonished them when to sow.

105. The Romans were accustomed yearly to sacrifice a dog to Sirius, to render him propitious in his influence upon their herds and fields. The eastern nations generally believed the rising of Sirius would be productive of great heat on the earth.

Thus Virgil:—

———"Tum steriles exurere Sirius agros;
Ardebant herbæ, et victum seges ægra negabat."

———"Parched was the grass, and blighted was the corn:
Nor 'scape the beasts; for Sirius from on high,
With pestilential heat infects the sky."

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103. Situation of Canis Major? How known? Supposed distance of Sirius? Illustrated by the speed of a cannon ball? Of light? 104. How was Sirius regarded by the ancients? Use made of it by the Thebans? The Egyptians? 105. Practice of the Romans?

106. Accordingly, to that season of the year when Sirius rose with the sun and seemed to blend its own influence with the heat of that luminary, the ancients gave the name of *Dog-days*, (*Dies canicularis.*) At that remote period the Dog-days commenced on the 4th of August, or four days after the summer solstice, and lasted forty days, or until the 14th of September. At present the dog-days begin on the 3d of July, and continue to the 11th of August, being one day less than the ancients reckoned.

107. Hence, it is plain that the Dog-days of the moderns have no reference whatever to the rising of Sirius, or any other star, because the *time* of their rising is perpetually accelerated by the precession of the equinoxes: they have reference then only to the summer solstice, which never changes its position in respect to the seasons.

The time of Sirius' rising varies with the latitude of the place, and in the same latitude, is sensibly changed after a course of years, on account of the precession of the equinoxes. This enables us to determine with approximate accuracy, the dates of many events of antiquity, which cannot be well determined by other records. We do not know, for instance, in what precise period of the world Hesiod flourished. Yet he tells us in his *Opera et Dies*, lib. ii. v. 185, that Arcturus in his time rose heliacally, 60 days after the winter solstice, which then was in the 9th degree of Aquarius, or 39° beyond its present position. Now 39° : 50¼″=2794 years since the time of Hesiod, which corresponds very nearly with history.

108. When a star rose at sun-setting, or set at sun-rising, it was called the *Achronical* rising or setting. When a planet or star appeared above the horizon just before the sun, in the morning, it was called the *Heliacal* rising of the star; and when it sunk below the horizon immediately after the sun, in the evening, it was called the *Heliacal* setting.

According to Ptolemy, stars of the *first* magnitude are seen rising and setting when the sun is 12° below the horizon; stars of the 2d magnitude require the sun's depression to be 13°; stars of the 3d magnitude, 14°, and so on, allowing one degree for each magnitude. The rising and setting of the stars described in this way, since this mode of description often occurs in Hesiod, Virgil, Columella, Ovid, Pliny, &c., are called *poetical* rising and setting. They served to mark the times of religious ceremonies, the seasons allotted to the several departments of husbandry, and the overflowing of the Nile.

109. The student may be perplexed to understand how the Dog Star, which he seldom sees till mid-winter, should be associated with the most fervid heat of summer. This is explained by considering that this star, in summer, is over our heads in the *daytime*, and in the lower hemisphere at night. As "thick the floor of heaven is inlaid with patines of bright gold," by day,

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106. Origin of the phrase *Dog-days?* When did they begin in the time of Virgil? At what time now? 107. What inference from these facts? What variation in the time of Sirius' rising? What calculation by knowing the time when Sirius rose, at any period? 108 What are the *Achronical* and *Heliacal* rising or setting of a star or planet? Remark of Ptolemy in regard to rising and setting of the stars? 109. How is it that Sirius, a winter star, is associated with the heat of summer?

as by night ; but on account of the superior splendor of the sun, we cannot see them.

110. Sirius is situated nearly S. of Alhena, in the feet of the Twins, and about as far S. of the equinoctial as Alhena is N. of it. It is about 10° E. of the Hare, and 26° S. of Betelguese in Orion, with which it forms a large equilateral triangle. It also forms a similar triangle with Phaet in the Dove, and Naos in the Ship. These two triangles being joined at their vertex in Sirius, present the figure of an enormous X, called by some, the EGYPTIAN X. Sirius is also pointed out by the direction of the Three Stars in the belt of Orion. Its distance from them is about 23°. It comes to the meridian at 9 o'clock on the 11th of February.

111. *Mirzam*, in the foot of the Dog, is a star of the 2d magnitude, $5\frac{1}{2}$° W. of Sirius. A little above, and 4° or 5° to the left, there are three stars of the 3d and 4th magnitudes, forming a triangular figure somewhat resembling a dog's head. The brightest of them, on the left, is called *Muliphen*. It entirely disappeared in 1670, and was not seen again for more than 20 years. Since that time it has maintained a steady lustre.

112. *Wesen* is a star of between the 2d and 3d magnitudes, in the back, 11° S. S. E. of Sirius, with which, and Mirzam in the paw, it makes an elongated triangle. The two hinder feet are marked by Naos and Lambda, stars of the 3d and 4th magnitudes, situated about 3° apart, and 12° directly S. of the fore foot. This constellation contains 31 visible stars, including one of the 1st magnitude, four of the 2d, and two of the 3d ; all of which are easily traced out by the aid of the map.

HISTORY.

Manilius, a Latin poet who flourished in the Augustan age, wrote an admirable poem, in five books, upon the fixed stars, in which he thus speaks of this constellation:

"All others he excels; no fairer light
Ascends the skies, none sets so clear and bright."

But EUDOSIA best describes it—

"Next shines the *Dog* with sixty-four distinct;
Famed for pre-eminence in envied song,
Theme of *Homeric* and Virgilian lays;
His fierce mouth flames with dreaded *Sirius;*
Three of his stars retire with feeble beams."

According to some mythologists, this constellation represents one of Orion's hounds, which was placed in the sky, near this celebrated huntsman. Others say it received its name in honor of the dog given by Aurora to Cephalus, which surpassed in speed all the

110. Situation of Sirius? What triangles? 111. Position and size of Mirzam? Other stars? Muliphen? 112. Wesen? What other stars? Whole number?
HISTORY.—What classical description of Canis Major? What different accounts of its origin?

animals of his species. Cephalus, it is said, attempted to prove this by running him against a fox, which, at that time, was thought to be the fleetest of all animals. After they had run together a long time, without either of them obtaining the victory, it is said that Jupiter was so much gratified at the fleetness of the dog, that he assigned him a place in the heavens.

But the name and form of this constellation are, no doubt, derived from the Egyptians, who carefully watched its rising, and by it judged of the swelling of the Nile, which they called Siris, and, in their hieroglyphical manner of writing, since it was, as it were, the sentinel and watch of the year, represented it under the figure of a dog. They observed that when Sirius became visible in the east, just before the morning dawn, the overflowing of the Nile immediately followed. Thus it warned them, like a faithful dog, to escape from the region of the inundation.

TELESCOPIC OBJECTS.

1, α Canis Majoris—A brilliant star, with a distant companion; R. A. 6h. 38m. 06s.; Dec. S. 16° 30′ 1. A 1, brilliant white; B 10, deep yellow, other distant small stars in the field.

2. δ Canis Majoris—A star with a distant companion in the loins; R. A. 7h. 01m. 53s.; Dec, S. 26° 08′ 6″. A 3½, light yellow; B 7½, very pale. Other small stars in the field, A line from *Betelguese* through *Sirius* intercepts it 12° below the latter star.

3. ε Canis Majoris (*Adhara*)—A star with a distant companion in the belly; R. A 6h. 52m. 20s. Dec. S. 28° 45′ 5″. A 2½, pale orange: B 7, violet. Found by running a line from the middle of Orion's belt through β just west of Sirius, to about 14° beyond the latter star.

4. A cluster in the back of the head; R. A. 6h. 52m. 10s.; Dec. S. 13° 29′ 2″. Tolerably compressed; stars of the 8th to 11th magnitudes, of which the four principal form the letter Y.

5. A cluster between Sirius and Monoceros; R. A. 7h. 10m. 35s.; Dec. S. 15° 21′ 4″. Stars principally of the 10th magnitude. Discovered by Miss Herschel in 1785.

CHAPTER V.

CONSTELLATIONS ON THE MERIDIAN IN MARCH.

ARGO NAVIS (the ship argo).—MAP III.

113. This constellation occupies a large space in the southern hemisphere, though but a small part of it can be seen in the United States. It is situated S. E. of Canis Major, and may be known by the stars in the prow and deck of the ship.

114. If a straight line joining Betelguese and Sirius, be produced 18° to the southeast, it will point out *Naos*, a star of the 2d magnitude, in the rowlock of the ship. This star is in the S. E. corner of the Egyptian X, and of the large equilateral triangle made by itself with Sirius and the Dove. When on the meridian, it is seen from this latitude about 8° above the south-

Telescopic Objects.—Alpha? Delta? Epsilon? What clusters?
113. Size and situation of Argo Navis? How known? 114. How find *Naos*, and where situated? How high when on the meridian?

ern horizon. It comes to the meridian on the 3d of March, about half an hour after Procyon, and continues visible but a few hours.

115. *Gamma*, in the middle of the ship, is a star of the 2d magnitude, about 7° S. of Naos, and just skims above the southern horizon for a few minutes, and then sinks beneath it. The principal star in this constellation is called, after one of the pilots, *Canopus;* it is of the 1st magnitude, 36° nearly S. of Sirius, and comes to the meridian 17 minutes after it ; but having about 53° of S. declination, it cannot be seen in the United States. The same is true of *Miaplacidus*, a star of the 1st magnitude in the oars of the ship, about 25° E. of Canopus, and 61° S. of Alphard, in the heart of Hydra.

An observer in the northern hemisphere, can see the stars as many degrees south of the equinoctial in the southern hemisphere, as his own latitude lacks of 90°, and no more.

116. *Markeb*, is a star of the 4th magnitude, in the prow of the ship, and may be seen from this latitude 16° S. E. of Sirius, and about 10° E. of Wesen, in the back of the Dog. This star may be known by its forming a small triangle with two others of the same magnitude, situated a little above it, on the E., 3° and 4° apart.

117. This constellation contains 64 stars, of which two are of the 1st magnitude, four of the 2d, and nine of the 3d. Most of these are too low down to be seen in the United States.

HISTORY.

This constellation is intended to perpetuate the memory of the famous ship which carried Jason and his 54 companions to Colchis, when they resolved upon the perilous expedition of recovering the golden fleece. The derivation of the word *Argo* has been often disputed. Some derive it from Argos, supposing that this was the name of the person who first proposed the expedition, and built the ship. Others maintain that it was built at Argos, whence its name. Cicero calls it Argo, because it carried Grecians, commonly called Argives. Diodorus derives the word from ἀργὸς, which signifies *swift*. Ptolemy says, but not truly, that Hercules built the ship, and called it Argo, after a son of Jason, who bore the same name. This ship had fifty oars, and being thus propelled must have fallen far short of the bulk of the smallest *ship* craft used by moderns. It is even said that the crew were able to carry it on their backs from the Danube to the Adriatic.

According to many authors, she had a beam on her prow, cut in the forest of Dodona by Minerva, which had the power of giving oracles to the Argonauts. This ship was the first, it is said, that ever ventured on the sea. After the expedition was finished, and Jason had returned in triumph, he ordered her to be drawn ashore at the isthmus of Corinth, and consecrated to Neptune, the god of the sea.

Sir Isaac Newton endeavors to settle the period of this expedition at about 30 years

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115. Size and situation of Gamma? Name the principal star in this constellation? Its magnitude? Is it ever seen in the U. S.? What said of Miaplacidus? Remark in fine print? 116. What said of Markeb? How known? 117. Number of stars in Argo Navis? Magnitudes?

HISTORY.—Design of this constellation? Import of the term *Argo?* Size and structure of the ship? What myth respecting this ship? What remark respecting Sir Isaac Newton? Dr. Bryant's opinion?

before the destruction of Troy, and 43 years after the death of Solomon. Dr. Bryant however, rejects the history of the Argonautic expedition as a mere fiction of the Greeks, and supposes that this group of stars, which the poets denominate Argo Navis, refers to Noah's ark and the deluge, and that the fable of the Argonautic expedition is founded on certain Egyptian traditions that related to the preservation of Noah and his family during the flood.

TELESCOPIC OBJECTS.

1. ι ARGO NAVIS—A star with a distant companion; R. A. 8h. 00m. 44s.; Dec. S. 23° 50′ 5″. A 3½, pale yellow; B 10, greyish. Other small stars in the field.

2. A SMALL GALAXY CLUSTER; R. A. 7h. 37m. 44s; Dec. S. 23° 29′ 1″.

3. A neat DOUBLE STAR over the ship's stern; R. A. 7h. 38m. 08s.; Dec. S. 14° 18′ 3″. A 7, silvery white; B 7½, pale white.

4 A close DOUBLE STAR over the Argo's stern; R. A. 7h. 40m. 27s.; Dec. S. 11° 48′ 3″ A 7½, pale yellow; B 9, light blue.

5. A bright PLANETARY NEBULA; R. A. 7h. 34m. 46s.; Dec. S. 17° 50′ 2″. A fine object, pale bluish white, and may be identified by several small stars in its vicinity. See Map VIII., Fig. 37.

CANCER (THE CRAB).—MAP III.

118. Cancer is now the fifth constellation and fourth sign of the Zodiac. It is situated in the ecliptic, between Leo on the E. and Gemini on the W. It contains 83 stars, of which one is of the 3d, and seven of the 4th magnitude. Some place the first-mentioned star in the same class with the other seven, and consider none larger than the 4th magnitude.

119. *Beta* is a star of the 3d or 4th magnitude, in the south-western claw, 10° N. E. of Procyon, and may be known from the fact that it stands alone, or at least has no star of the same magnitude near it. It is midway between Procyon and Acubens.

120. *Acubens,* is a star of similar brightness, in the south-eastern claw, 10° N. E. of Beta, and nearly in a straight line with it and Procyon. An imaginary line drawn from Capella through Pollux, will point out Acubens, at the distance of 24° from Pollux. It may be otherwise distinguished by its standing between two very small stars close by it in the same claw.

121. The southern Asellus, marked Delta, is situated in the line of the ecliptic, and, in connection with Wasat and Tejat, marks the course of the earth's orbit for a space of 36° from the solstitial colure.

A few degrees S. of Cancer, and about 17° E. of Procyon, are four stars of the 4th magnitude, 3° or 4° apart, which mark the head of Hydra. The rest of this constellation is delineated on Map IV.

TELESCOPIC OBJECTS.—Iota? What cluster? Double stars? Nebula? Point out on the map?
118. Place of Cancer in the Zodiac? In other respects? Number and size of its stars? 119. Beta? How known? 120. Acubens? How found? 121. Situation of Delta? Remarks respecting Hydra? Respecting the sign Cancer?

The beginning of the *sign* Cancer (not the constellation) is called the *Tropic of Cancer*, and when the sun arrives at this point, it has reached its utmost limit of north declination, where it seems to remain stationary a few days before it begins to decline again to the south. This stationary attitude of the sun is called the summer *solstice;* from two Latin words signifying the *sun's standing still.* The distance from the first point of Cancer to the equinoctial, which, at present, is 23° 27⅔', is called the *obliquity of the ecliptic.* It is a remarkable and well ascertained fact, that this is continually growing less and less. The tropics are slowly and steadily approaching the equinoctial, at the rate of about half a second every year; so that the sun does not now come so far north of the equator in summer, nor decline so far south in winter, as it must have done at the creation, by nearly a degree.

HISTORY.

In the Zodiacs of Esne and Dendera, and in most of the astrological remains of Egypt, a Scarabæus, or Beetle, is used as the symbol of this sign; but in Sir William Jones' Oriental Zodiac, and in some others found in India, we meet with the figure of a crab. As the Hindoos, in all probability, derived their knowledge of the stars from the Chaldeans, it is supposed that the figure of the crab, in this place, is more ancient than the Beetle.

In some eastern representations of this sign, two animals, like asses, are found in this division of the Zodiac; and as the Chaldaic name for the ass may be translated *muddiness*, it is supposed to allude to the discoloring of the Nile, which river was rising when the sun entered Cancer. The Greeks, in copying this sign, have placed two asses as the appropriate symbol of it, which still remain. They explain their reason, however, for adopting this figure, by saying that these are the animals that assisted Jupiter in his victory over the giants.

Dopuis accounts for the origin of the asses in the following words:—"Le Cancer ou sont les étoiles appellées les ânes, forme l'empreinte du pavillon d' Issachar que Jacob assimile à l'âne."

Mythologists give different accounts of the origin of this constellation. The prevailing opinion is, that while Hercules was engaged in his famous contest with the dreadful Lernæan monster, Juno, envious of the fame of his achievements, sent a sea-crab to bite and annoy the hero's feet, but the crab being soon dispatched, the goddess, to reward its services, placed it among the constellations.

"The Scorpion's claws here clasp a wide extent,
And here the Crab's in lesser clasps are bent."

TELESCOPIC OBJECTS.

1. *δ* Cancri—A very delicate double star, under the Crab's mouth; R. A. 8h. 35m. 35s.; Dec. N. 18° 44' 04". A 4½, straw color; B 15 blue, only seen by glimpses.

2. *ε* Cancri—A star with a distant companion, on the Crab's body; R. A. 8h. 31m. 16s.; Dec. N. 20° 06' 02". A 6½, and B 7, both pale white; and a third star in the field of nearly the same magnitude.

3. *ζ* Cancri—A fine triple star, just below the after claws of the Crab; R. A. 8h. 03m. 02s.; Dec. N. 18° 07' 05". A 6, yellow; B 7, orange tinge; C 7½, yellowish. Supposed to be a Ternary system.

4. About 7° northeasterly from Tegmine, is a nebulous cluster of very minute stars, in the crest of Cancer, sufficiently luminous to be seen by the naked eye. It is situated in a triangular position with regard to the head of the Twins and the Little Dog. It is about 20° W. of each. It may otherwise be discovered by means of two conspicuous stars of the 4th magnitude, lying one on either side of it, at the distance of about 2°, called the *northern* and *southern Aselli.* By some of the Orientalists, this cluster was denominated *Præsepe*, the *Manger*, a contrivance which their fancy filled up for the accommodation of the *Aselli* or *Asses;* and it is so called by modern astronomers. The appearance of this group to the unassisted eye, is not unlike the nucleus of a comet, and it was repeatedly mistaken for the comet of 1832, which, in the month of November, passed in its neighborhood. Map VIII., Fig. 38.

5. A rich but loose cluster in the Crab's southern claw, where a line from Rigel through Procyon, into the east-northeast, will find it about 5° north of *ε* in the Hyades; R. A. 8h. 42m. 26s.; Dec. N. 12° 23' 06". Stars mostly of the 9th and 10th magnitudes. See Map VIII., Fig. 39.

History.—What other figures for Cancer? Egyptian? Hindoo? Greek? Origin of this constellation?

Telescopic Objects.—Delta? Epsilon? Zeta? What Clusters? Point out on the Map

CHAPTER VI.

CONSTELLATIONS ON THE MERIDIAN IN APRIL.

LEO (THE LION).—MAP IV.

122. LEO is one of the most brilliant constellations in the winter hemisphere, and contains an unusual number of very bright stars. It is situated next E. of Cancer, and directly S. of Leo Minor and the Great Bear.

The Hindoo astronomer, Våraha, says, "Certainly the southern solstice was once in the middle of *Asleha* (*Leo*); the northern in the first degree of *Dhanishta*" (*Aquarius*). Since that time, the solstitial, as well as the equinoctial points, have gone backward on the ecliptic 75°. This divided by 50¼″, gives 5373 years; which carry us back to the year of the world 464. Sir W. Jones says, that Varaha lived when the solstices were in the first degrees of Cancer and Capricorn; or about 400 years before the Christian era.

123. Leo is the *fifth sign*, and the *sixth* constellation of the Zodiac. The mean right ascension of this extensive group is 150°, or 10 hours. Its center is therefore on the meridian the sixth of April. Its western outline, however, comes to the meridian on the 18th of March, while its eastern limit does not reach it before the 3d of May.

This constellation contains 95 visible stars, of which one is of the 1st magnitude, one of the 2d, six of the 3d, and fifteen of the 4th.

> "One splendid star of highest dignity,
> One of the second class the Lion boasts,
> And justly figures the fierce summer's rage."

124. The principal star in this constellation is of the 1st magnitude, situated in the breast of the animal, and named *Regulus*, from the illustrious Roman consul of that name.

It is situated almost exactly in the ecliptic, and may be readily distinguished on account of its superior brilliancy. It is the largest and lowest of a group of five or six bright stars which form a figure somewhat resembling a sickle, in the neck and shoulder of the Lion. There is a little star of the 5th magnitude, about 2° S. of it, and one of the 3d magnitude 5° N. of it, which will serve to point it out.

Great use is made of Regulus by nautical men, for determining their longitude at sea. Its *latitude*, or distance from the *ecliptic*, is less than ½°; but its *declination*, or distance from the *equinoctial*, is nearly 13° N.; so that its meridian altitude will be just

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122. Describe Leo. Its situation? What remarkable statement of Varaha? Calculations upon it? 123. Position of Leo in the Zodiac? When on the meridian? Number and size of its stars? 124. Its principal star? Situation? How distinguished? What use made of Regulus? When on the meridian, where are Castor and Pollux?

equal to that of the sun on the 19th of August. Its right ascension is very nearly 150°. It therefore culminates about 9 o'clock on the 6th of April.

When Regulus is on the meridian, Castor and Pollux are seen about 40° N. W. of it, and the two stars in the Little Dog are about the same distance in a S. W. direction; with which, and the two former, it makes a large isosceles triangle whose vertex is at Regulus.

125. The next considerable star is 5° N. of Regulus, marked *Eta*, situated in the collar ; it is of between the 3d and 4th magnitudes, and with Regulus constitutes the handle of the sickle. Those three or four stars of the 3d magnitude, N. and W. of Eta, arching round with the neck of the animal, describe the blade.

126. *Al Gieba* is a bright star of the 2d magnitude, situated in the shoulder, 4° in a N. E. direction from Eta, and may be easily distinguished by its being the brightest and middle one of the three stars lying in a semicircular form curving toward the west; and it is the first in the blade of the sickle.

127. *Adhafera* is a star of the 3d magnitude, situated in the neck, 4° N. of *Al Gieba*, and may be known by a very minute star just below it. This is the second star in the blade of the sickle.

128. *Ras al Asad*, situated before the ear, is a star of the 3d or 4th magnitude, 6° W. of Adhafera, and is the third in the blade of the sickle. The next star, *Epsilon*, of the same magnitude, situated in the head, is 2½° S. W. of Ras al Asad, and a little *within* the curve of the sickle. About midway between these, and a little to the E., is a very small star hardly visible to the naked eye.

129. *Lambda*, situated in the mouth, is a star of the 4th magnitude, 3½° S. W. of Epsilon, and the last in the sickle's point. *Kappa*, situated in the nose, is another star of the same magnitude, and about as far from Lambda as Epsilon. Epsilon and Kappa are about 4½° apart, and form the longest side of a triangle, whose vertex is in Kappa.

130. *Zozma*, situated in the back of the Lion, is a star of the 3d magnitude 18° N. E. of Regulus, and midway between it and Coma Berenices, a fine cluster of small stars, 18° N. E. of Zozma.

131. *Theta*, situated in the thigh, is another star of the 3d magnitude, 5° directly S. of Zozma, and so nearly on the same meridian that it culminates but one minute after it. This star

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125. Next principal star—size and position? 126. Al Gieba? How known? 127. Adhafera? 128. Ras al Asad? Epsilon? 129. Situation and size of Lambda? Of Kappa? 130. Of Zozma? 131. Of Theta? What triangle? What other stars mentioned?

makes a right-angled triangle with Zozma on the N. and Denebola on the E., the right angle being at Theta.

Nearly in a straight line with Zozma and Theta, and south of them, are three or four smaller stars, 4° or 5° apart, which mark one of the legs.

132. *Denebola* is a bright star of the first magnitude, in the brush of the tail, 10° S. E. of Zozma, and may be distinguished by its great brilliancy. It is 5° W. of the equinoctial colure, and comes to the meridian 1 hour and 41 minutes after Regulus, on the 3d of May; when its meridian altitude is the same as the sun's at 12 o'clock the next day.

When Denebola is on the meridian, Regulus is seen 25° W. of it, and Phad, in the square of Ursa Major, bears 39° N. of it. It forms, with these two, a large right-angled triangle; the right angle being at Denebola. It is so nearly on the same meridian with Phad that it culminates only four minutes before it.

Denebola is 35½" W. of Arcturus, and about the same distance N. W. of Spica Virginis, and forms, with them, a large equilateral triangle on the S. E. It also forms with Arcturus and Cor Caroli a similar figure, nearly as large on the N. E. These two triangles, being joined at their base, constitute a perfect geometrical figure of the form of a Rhombus, called by some, the DIAMOND OF VIRGO.

A line drawn from Denebola through Regulus, and continued 7° or 8° further in the same direction, will point out *Xi* and *Omicron*, of the 3d and 4th magnitudes, situated in the foreclaws, and about 3° apart.

There are a number of other stars of the 3d and 4th magnitudes in this constellation, which require no description, as the scholar will easily trace them out from the map. The position of Regulus and Denebola are often referred to in the geography of the heavens, as they serve to point out other clusters in the same neighborhood.

HISTORY.

According to Greek fable, this Lion represents the formidable animal which infested the forests of Nemæa. It was slain by Hercules, and placed by Jupiter among the stars in commemoration of the dreadful conflict. Some writers have applied the story of the twelve labors of Hercules to the progress of the sun through the twelve signs of the ecliptic; and as the combat of that celebrated hero with the Lion was his first labor, they have placed Leo as the *first sign*. The figure of the Lion was, however, on the Egyptian charts long before the invention of the fables of Hercules. It would seem, moreover, according to the fable itself, that Hercules, who represented the sun, actually slew the Nemæan Lion, because *Leo* was already a zodiacal sign.

In hieroglyphical writing the Lion was an emblem of violence and fury; and the representation of this animal in the Zodiac, signified the intense heat occasioned by the sun when it entered that part of the ecliptic. The Egyptians were much annoyed by lions during the heat of summer, as they at that season left the desert, and haunted the banks of the Nile, which had then reached its greatest elevation. It was therefore natural for their astronomers to place the Lion where we find him in the Zodiac.

The figure of Leo, very much as we now have it, is in all the Indian and Egyptian Zodiacs. The overflowing of the Nile, which was regularly and anxiously expected every year by the Egyptians, took place when the sun was in this sign. They therefore paid more attention to it, it is to be presumed, than to any other. This was the principal reason, Mr. Green supposes, why Leo stands first in the zodiacs of Dendera.

In the Hebrew Zodiac, Leo is assigned to Judah, on whose standard, according to all traditions, a Lion is painted. This is clearly intimated in numerous passages of the Hebrew writings: Ex.—"Judah is a Lion's whelp; he stooped down, he couched as a

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132. Size and position of Denebola? How known? When does it come to the meridian as compared with Regulus? What said of its meridian altitude? When on the meridian where is Regulus seen? Phad? What triangle? How is Denebolo situated with respect to Arcturus and Spica Virginis? To Cor Caroli? What other large figures?

HISTORY.—Greek fable? Egyptian? Hebrew Zodiacs? Scripture allusions to the Lion?

Lion, and as an Old Lion; who shall rouse him up?" Gen. xlix. 9. "The Lion of the tribe of Judah hath prevailed." Rev. v. 5.

TELESCOPIC OBJECTS

1. α Leonis (*Regulus*)—A bright star with a distant companion; R. A. 9h. 59m. 51s.; Dec. N. 12° 44′ 08″. A 1, flushed white; B 8½, pale purple.

2. β Leonis (*Denebola*)—A fine star with a distant companion; R. A. 11h. 40m. 54s.; Dec. N. 15° 28′ 0″. A 2½, bluish; B 8, dull red.

3. γ Leonis (*Al Gieba*)—A splendid double star; R. A. 10h. 11m. 08s.; Dec. N. 20° 39′ 0″. A 2, bright orange; B 4, greenish yellow. A most beautiful object—binary-period supposed about 1000 years. Map VIII., Fig. 6.

4. δ Leonis (*Zozma*)—A coarse triple star; R. A. 11h. 05m. 35s.; Dec. N. 21° 24′ 1″. A 3, pale yellow; B 13, blue; C 9, violet.

5. ε Leonis—A star with a distant companion in the mouth of Leo; R. A. 9h. 30m. 46s; Dec. N. 24° 30′ 5″. A 3, yellow; B 10, pale grey.

6. ι Leonis—A binary star in the flank, 7° S. W. of Denebola (F on map); R. A. 11h. 15m. 35s.; Dec. N. 11° 24′ 8″. It forms a neat scalene triangle with β and ϑ. A 4, pale yellow; B 7½, light blue; a beautiful object.

7. μ Leonis (*Ras Al Asad*)—A double star; R. A. 9h. 43m. 39s.; Dec. N. 26° 46′ 5″. A 3, orange; B 10, pale lilac.

8. A neat double star near Zozma; R. A. 11h. 05m. 17s.; Dec. 21° 00′ 3″. Components both 7½, and both faint yellow; a beautiful object.

9. A bright nebula near the hind paws; R. A. 10h. 57m. 37s.; Dec. N. 0° 49′ 6″. Large, elongated, well-defined—an enormous mass of luminous matter—one of a vast number of spherical nebulæ in the vicinity.

10. A bicentral white nebula in the lower jaw, 2° south of λ Leonis; R. A. 9h. 23m. 07s.; Dec. N. 22° 12′ 1″. May be classed as double—small stars in field; difficult object. See Map VIII., Fig. 40.

11. A lucid white nebula on the Lion's ribs, about 9° due east of Regulus; R. A. 10h. 35m. 31s.; Dec. N. 12° 31′ 9″. Round and bright, with two small stars in field. Another large pale white nebula, about 1° east of it.

12. A pair of bright class nebulæ in the Lion's belly; R. A. 10h. 39m. 49s.; Dec. N. 13° 28′. Found south of line joining Regulus and ϑ Leonis, about 10° east of, and nearly on a parallel with the latter.

13. A large, elongated nebula, with a bright nucleus on the Lion's haunch; R. A. 11h. 11m. 48s.; Dec. N. 13° 52′ 4″; just 3° southeast of ϑ, with another smaller nebula, and several stars in the field. Map VIII., Fig. 41.

LEO MINOR (THE LITTLE LION).—MAP IV.

133. Leo Minor contains 53 stars, including only one of the 3d magnitude, and five of the 4th. The principal star is situated in the body of the animal, 13° N. of Gamma Leonis, in a straight line with Phad, and may be known by a group of smaller stars, a little above it on the N. W.

It forms an equilateral triangle with Gamma and Delta Leonis, the vertex being in Leo Minor. This star is marked with the letter *l*, in modern catalogues, and being the principal representative of the constellation, is itself sometimes called the Little Lion: 8° E. of this star (the Little Lion) are two stars of the 4th magnitude, in the last paw of Ursa Major, and about 10° N. W. of it are two other stars of the 3d magnitude, in the first hind paw.

"The *Smaller Lion* now succeeds; a cohort
Of fifty stars attend his steps;
And *three*, to sight unarm'd, invisible."

Telescopic Objects.—Alpha? Beta? Gamma? Point out on the map. Delta? Epsilon? Iota? Mu? What nebulæ? Which shown on the map? Point out.
133. Describe Leo Minor? Its principal star? Helps form what triangle?

134. This constellation was formed by Hevelius, out of the *Stellæ informes*, or unformed stars of the ancients, which lay scattered between the Zodiacal constellation Leo on the S., and Ursa Major on the N. Its mean right ascension is the same with that of Regulus, and it comes to the meridian at the same time on the 6th of April.

The modern constellations, or those which have been added to our celestial maps since the adoption of the Greek notation, in 1603, are referred to by the letters of the English alphabet instead of the Greek. This is the case in regard to Leo Minor, and all other constellations whose origin is subsequent to that period.

TELESCOPIC OBJECTS.

A BRIGHT OVAL NEBULA between Lynx and Cancer, but given to Leo Minor; R. A. 8h. 42m. 44s.; Dec. N. 34° 00′ 6″. Direct telescope 16° north by east of Presepe in Cancer.

SEXTANS (THE SEXTANT).—MAP IV.

135. Sextans contains 41 very small stars, including only one as large as the 4th magnitude. This is situated very near the equinoctial, 13° S. of Regulus, and comes to the meridian about the same time on the 6th of April. The other stars in this constellation are too small to engage attention. A few of the largest of them may be traced out from the map.

The SEXTANT, called also URANIA'S SEXTANT, is a modern constellation that Hevelius made out of the unformed stars of the ancients, which lay scattered between the Lion on the N., and Hydra on the S.

Urania was one of the muses, and daughter of Jupiter and Mnemosyne. She presided over astronomy. She was represented as a young virgin, dressed in an azure-colored robe, crowned with stars, holding a robe in her hands, and having many mathematical instruments about her.

A sextant, in mathematics, is the sixth part of a circle, or an arc comprehending 60 degrees. But the term is more particularly used to denote an astronomical instrument well known to mariners. Its use is the same as that of the quadrant: namely, to measure the angular distance, and take the altitude of the sun, moon, planets, and fixed stars. It is indispensable to the mariner in finding the latitude and longitude at sea, and should be in the hands of every surveyor and practical engineer. It may serve the purpose of a theodolite, in measuring inaccessible heights and distances. It may gratify the young pupil to know, that by means of such an instrument, well adjusted, and with a clear eye and a steady hand, he could readily tell, within a few hundred yards how far north or south of the equator he was, and that from any quarter of the world. known or unknown. This constellation is so called, on account of a supposed resemblance to this instrument.

TELESCOPIC OBJECTS.

1. A DOUBLE STAR on the right fore leg of Leo, though crimped into the sextant; R. A 9h. 45m. 45s.; Dec. N. 5° 41′ 8″. It lies about one-third of the way from Regulus to Alphard. A 7, and B. 9, both blue, and well-defined.

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134. Origin of Leo Minor? Mean R. A.? What remark respecting the *notation* of the stars?

TELESCOPIC OBJECTS.—What nebula? Situation? How find?

135. Describe Sextans? Situation of its principal star? What said of the remainder? What said of the age of this constellation? Of Urania? Of the Sextant as a nautical instrument?

TELESCOPIC OBJECTS.—What double stars? What nebula? What remarkable sight seen near this nebula?

2. A neat DOUBLE STAR on the north extreme of the graduated limb of the instrument; and three-fifths of the distance between Alphard and Denebola; R. A. 10h. 35m. 02s.; Dec. N. 5° 35′ 2″. A 7, topaz yellow; B 8, smalt blue; a fine object.

3. A bright class ROUND NEBULA on the frame of the instrument; R. A. 10h. 05m. 58s.; Dec. N. 4° 15′ 1″. A good telescope shows another large but faint nebula near by.

This object is on or near the spot where the Capuchin, De Rheita, fancied he saw the napkin of St. Veronica, in 1783. Captain Smyth has a picture of this wonderful napkin; and Sir J. Herschel remarks that "many strange things were seen among the stars before the use of powerful telescopes became common."

HYDRA AND THE CUP.—MAP IV.

136. HYDRA, (*the Water-Serpent,*) is an extensive constellation, winding from E. to W. in a serpentine direction, over a space of more than 100 degrees in length. It lies south of Cancer, Leo and Virgo, and reaches almost from Canis Minor to Libra. It contains sixty stars, including one of the 2d magnitude, three of the 3d, and twelve of the 4th.

137. *Alphard* or *Cor Hydræ,* in the heart, is a lone star of the 2d magnitude, 23° S. S. W. of Regulus, and comes to the meridian at the same time with Lambda, in the point of the sickle, about 20 minutes before 9 o'clock on the 1st of April. There is no other considerable star near it, for which it can be mistaken. An imaginary line drawn from Gamma Leonis through Regulus, will point out Cor Hydræ, at the distance of 23°.

138. The head of Hydra may be distinguished by means of four stars of the 4th magnitude, $2\frac{1}{2}°$ and 4° apart, situated 6° S. of Acubens, and forming a rhomboidal figure. The three upper stars in this cluster form a small arch, and may be known by two very small stars just below the middle one, making with it a very small triangle. The three western stars in the head also make a beautiful little triangle. The eastern star in this group, marked *Zeta*, is about 6° directly S. of Acubens, and culminates at the same time.

139. When Alphard is on the meridian, *Alkes*, of the 4th magnitude, situated in the bottom of the Cup, may be seen 24° S. E. of it, and is distinguished by its forming an equilateral triangle with Beta and Gamma, stars of the same magnitude, 6° S. and E. of it. Alkes is common both to Hydra and the Cup. Beta, on the S., is in Hydra, and Gamma, on the N. E., is near the middle of the Cup. A line drawn from Zozma, through Theta

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136. Describe Hydra? Its situation? Number and magnitude of its stars? 137. Position and magnitude of Alphard? How pointed out? 138. How is the *head* of Hydra distinguished? 139. What said of Alkes? Of Beta and Gamma? How is Beta found?

Leonis, and continued 38½° directly S. will reach Beta ; it is therefore on the same meridian, and will culminate at the same time on the 23d of April.

140. The Cup itself (called also the *Crater*), may be easily distinguished by means of six stars of the 4th magnitude, forming a beautiful crescent, or semicircle , opening to the W. The center of this group is about 15° below the equinoctial, and directly S. of the hinder feet of Leo. The crescent form of the stars in the Cup is so striking and well defined, when the moon is absent, that no other description is necessary to point them out. Its center comes to the meridian about two hours after Alphard, on the same evening ; and consequently, it culminates at 9 o'clock, one month after Alphard does. The remainder of the stars in this constellation may be easily traced by aid of the map.

141. When the head of Hydra is on the meridian, its other extremity is many degrees below the horizon, so that its whole length cannot be traced out in the heavens until its center, or the Cup, is on the meridian.

> ———"Near the equator rolls
> The sparkling Hydra, proudly eminent
> To drink the *Galaxy's* refulgent sea ;
> Nearly a fourth of the encircling curve
> Which girds the ecliptic, his vast folds involve ;
> Yet *ten* the number of his stars diffused
> O'er the long track of his enormous spires ;
> *Chief* beams his heart, sure of the second rank,
> But emulous to gain the first."—*Eudosia.*

HISTORY.

The astrologers of the east, in dividing the celestial hosts into various compartments, assigned a popular and allegorical meaning to each. Thus the sign *Leo*, which passes the meridian about midnight, when the sun is in Pisces, was called *the House of the Lions*, Leo being the domicil of Sol.

The introduction of two serpents into the constellations of the ancients, had its origin, it is supposed, in the circumstances that the polar one represented the oblique course of the stars, while the Hydra, or Great Snake, in the southern hemisphere, symbolized the moon's course ; hence the *Nodes* are called *the Dragon's head and tail to this day.*

The hydra was a terrible monster, which, according to mythologists, infested the neighborhood of the lake Lerna, in the Peloponnesus. It had a hundred heads, according to Diodorous ; fifty, according to Simonides ; and nine, according to the more commonly received opinion of Apollodorus, Hyginus, and others. As soon as one of these heads was cut off, two immediately grew up if the wound was not stopped by fire.

> "Art thou proportion'd to the hydra's length,
> Who by his wounds received augmented strength ?
> He raised a hundred hissing heads in air,
> When one I lopp'd, up sprang a dreadful pair."

To destroy this dreadful monster, was one of the labors of Hercules, and this he easily effected with the assistance of Iolaus, who applied a burning iron to the wounds as soon as one head was cut off. While Hercules was destroying the hydra, Juno, jealous of his glory, sent a sea-crab to bite his foot. This new enemy was soon despatched ; and

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140. How is the Cup distinguished ? Is it easily found ? 141. What is said of the extent of Hydra east and west ? History of Hydra ?

Juno was unable to succeed in her attempts to lessen the fame of Hercules. The conqueror dipped his arrows in the gall of the Hydra, which ever after rendered the wounds inflicted with them incurable and mortal.

This fable of the many-headed hydra may be understood to mean nothing more than that the marshes of Lerna were infested with a multitude of serpents, which seemed to multiply as fast as they were destroyed.

TELESCOPIC OBJECTS.

1. *α* CRATERIS—A star with two very distant companions in the base of the cup; R. A. 10h. 52m. 00s; Dec. S. 17° 26′ 9″. A. 4, orange tint; B 8, intense blood color; C 9, pale blue.
2. *γ* CRATERIS—A close DOUBLE STAR, in the center of the cup; R. A. 11h. 16m. 54s.; Dec. S. 16° 48′ 3″; A 4, bright white; B 14, grey, with a star of the 11th magnitude following, on a line with A. B. 25′ distant.
3. *δ* CRATERIS—A star with a very distant companion, on the cup, midway between Alphard and Spica, but a little south of the line joining them; R. A. 11h. 11m. 21s.; Dec. S. 13° 54′ 8″. A 3½, pale orange; B 11, pale blue—other small stars in the field.
4. *α* HYDRÆ (*Cor Hydræ*)—A bright star in the heart of Hydra with a distant companion; R. A. 1h. 19m. 44s.; Dec. S. 7° 58′ 1″. A 2, orange tint; B 10, pale green.
5. *δ* HYDRÆ—A star with a distant companion in the head of Hydra; R. A. 8h. 29m. 14s.; Dec. N. 6° 15′ 5″. A 4, light topaz; B 9, livid—several other stars in the field.
6. *ε* HYDRÆ—A double star in the head; R. A. 8h. 38m. 18s.; Dec. N. 7° 00′ 2″. A 4, pale yellow; B 8½, purple.
7. A PLANETARY NEBULA in the middle of the body; R. A. 10h. 17m. 01s.; Dec. S. 17° 50′ 6″; greyish white.

CHAPTER VII.

CONSTELLATIONS ON THE MERIDIAN IN MAY.

URSA MAJOR (THE GREAT BEAR).—MAPS IV. AND VI.

142. URSA MAJOR is situated between Ursa Minor on the north, and Leo Minor on the south. It is one of the most noted and conspicuous in the northern hemisphere. It has been an object of universal observation in all ages of the world.

The priests of Belus and the Magi of Persia, the shepherds of Chaldea, and the Phœnician navigators, seem to have been equally struck with its peculiar outlines. And it is somewhat remarkable, that a remote nation of American Aborigines, the Iroquois, and the earliest Arabs of Asia, should have given to the very same constellation the name of "Great Bear," when there had probably never been any communication between them; and when the name itself is so perfectly arbitrary, there being no resemblance whatever to a bear, or to any other animal.

143. It is readily distinguished from all others by means of a remarkable cluster of seven bright stars, forming what is familiarly termed the *Dipper*, or *Ladle*. In some parts of England it is called "Charles' Wain," or wagon, from its fancied resem-

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TELESCOPIC OBJECTS.—Alpha? Gamma? Delta? Alpha Hydræ? Delta Hydræ? Eta Hydræ? What Nebula?

142. Describe Ursa Major? What remarkable fact as to its name? 143. How distinguished? What other names for the Dipper? What remark in small type?

blance to a wagon drawn by three horses in a line. Others call it the Plough. The cluster, however, is more frequently put for the whole constellation, and called simply the Great Bear.

We see no reason to reject the very appropriate appellation of the shepherds, for the resemblance is certainly in favor of the Dipper; the four stars in the square forming the bowl, and the other three the handle.

144. When the Dipper is on the meridian, above the pole, the bottom lies toward us, with the handle on the right.

Benetnasch is a bright star of the 2d magnitude, and is the first in the handle. The second, or middle star in the handle is *Mizar*, 7° distant from Benetnasch. It may be known by means of a very minute star almost touching it, called *Alcor*.

145. The third star in the handle is called *Alioth*, and is about $4\frac{1}{2}°$ W. of Mizar. Alioth is very nearly opposite Shedir in Cassiopeia, and at an equal distance from the pole. Benetnasch, Mizar, and Alioth constitute the handle, while the next four in the square form the bowl of the Dipper.

146. Five and a half degrees W. of Alioth is the first star in the *top* of the Dipper, at the junction of the handle, called *Megrez;* it is the smallest and middle one of the cluster, and is used in various observations both on sea and land for important purposes.

When Megrez and Caph have the same altitude, and are seen in the same horizontal line east and west, the polar star is then at its greatest elongation from the true pole of the heavens; and this is the proper time for an observer to take its angle of elevation, in order to determine the *latitude*, and its azimuth or angle of declination, in order to determine the magnetic variation.

147. At the distance of $4\frac{1}{2}°$ S. W. of Megrez is *Phad*, the first star in that part of the bottom which is next the handle.

The stars in this cluster are so well known, and may be so easily described without reference to their relative bearings, that they would rather confuse than assist the student, were they given with ever so much accuracy. The several bearings for this cluster were taken when Megrez was on the meridian, and will not apply at any other time, though their respective distances will remain the same.

148. At the distance of 8° W. of Phad, is the westernmost star in the bottom of the Dipper called *Merak*. The bright star 5° N. of it, toward the pole, is called *Dubhe*. These two, are, by common consent, called the *Pointers*, because they always point toward the pole; for, let the line which joins them be continued in the same direction $28\frac{3}{4}°$ further, it will just reach the north pole.

The names, positions, and relative distances of the stars in this cluster should be well

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144. How is the handle of the Dipper situated, when the Dipper is above the pole? Describe Benetnasch? Mizar? How known? 145. Alioth? Megrez? Remark respecting? Phad? Remark in small print? 148. Merak and Dubhe? Constitute what? Remark respecting the names, positions and distances of the stars in Ursa Major? Why should these distances be well understood?

remembered, as they will be frequently adverted to. The distance of Dubhe, or the Pointer nearest to the north pole, is 28¾°. The distance between the two upper stars in the Dipper is 10°; between the two lower ones is 8°; the distance from the brim to the bottom next the handle, is 4½°; between Megrez and Alioth, is 5½°; between Alioth and Mizar, 4½°; and between Mizar and Benetnasch, 7°.

The reason why it is important to have these distances clearly settled in the mind is, that these stars, being always in view, and more familiar than any other, the student will never fail to have a standard measure before him, which the eye can easily make use of in determining the distances between other stars.

149. The position of Megrez in Ursa Major, and of Caph in Cassiopeia, is somewhat remarkable. They are both in the equinoctial colure, almost exactly opposite each other, and equally distant from the pole. Caph is in the colure, which passes through the vernal equinox, and Megrez is in that which passes through the autumnal equinox. The latter passes the meridian at 9 o'clock, on the 10th of May, and the former just six months afterward, at the same hour, on the 10th of November.

150. *Psi*, in the left leg of Ursa Major, is a star of the 4th magnitude, in a line with Megrez and Phad, distant from the latter 12½°. A little out of the same line, 3° farther, is another star of the 4th magnitude, marked *Epsilon*, which may be distinguished from Psi, from its forming a straight line with the two *Pointers*.

151. The right fore-paw, and the two hinder ones, each about 15° from the other, are severally distinguished by two stars of the 4th magnitude, between 1° and 2° apart. These three duplicate stars are nearly in a right line, 20° S. of, and in a direction nearly parallel with Phad and Dubhe, and are the only stars in this constellation that ever set in this latitude.

There are a few other stars of equal brightness with those just described, but amidst the more splendid and interesting group with which they are clustered, they seldom engage our observation.

The whole number of visible stars in this constellation is 87; of which five are of the 2d, two of the 3d, and about twice as many of the 4th magnitude.

HISTORY.

URSA MAJOR is said to be Calisto, or Helice, daughter of Lycaon, king of Arcadia. She was an attendant of Diana, and mother of Arcas, by Jupiter, who placed her among the constellations, after the jealousy of Juno had changed her into a bear.

"This said, her hand within her hair she wound,
Swung her to earth, and dragg'd her on the ground;
The prostrate wretch lifts up her hand in prayer;
Her arms grow shaggy, and deform'd with hair,
Her nails are sharpen'd into pointed claws,
Her hands bear half her weight, and turn to paws;
Her lips, that once could tempt a god, begin
To grow distorted in an ugly grin;

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149. What said of Megrez and Caph? 150. Of Psi and Epsilon? 151. How find the *feet* of the figure? Number of stars in Ursa Major? Magnitudes?

HISTORY.—Who was Ursa Major before she became a bear? What other supposition? How are the two bears represented by the Egyptians? What further remarks?

And lest the supplicating brute might reach
The ears of Jove, she was deprived of speech.
* * * * * * *
How did she fear to lodge in woods alone,
And haunt the fields and meadows, once her own!
How often would the deep-mouth'd dogs pursue,
Whilst from her hounds the frighted hunters flew."—*Ovid's Met.*

Some suppose that her son Arcas, otherwise called Bootes, was changed into Ursa Minor, or the Little Bear. It is well known, that the ancients represented both these constellations under the figure of a wagon drawn by a team of horses; hence the appellation of *Charles' Wain*, or wagon. This is alluded to in the Phenomena of Aratus, a Greek poem, from which St. Paul quotes in his address to the Athenians:—

"The one call'd Helix, soon as day retires,
Observed with ease lights up his radiant fires.
The other, smaller, and with feebler beams,
In a less circle drives its lazy teams;
But more adapted for the sailor's guide,
Whene'er, by night, he tempts the briny tide."

In the Egyptian planispheres of remote antiquity, these two constellations are represented by the figures of bears, instead of wagons; and the Greeks, who derived most of their astronomical symbols from the Egyptians, though they usually altered them to emblems of their own history or superstition, have, nevertheless, retained the original form of the two bears. It is said by Aratus, that the Phœnician navigators made use of Ursa Minor in directing their voyages:—

"Observing this, Phœnicians plough the main:"

while the Greeks confined their observations to Ursa Major.

Some imagine that the ancient Egyptians arranged the stars near the North Pole, within the outlines of a bear, because the polar regions are the haunts of this animal, and also because it makes neither extensive journeys nor rapid marches.

At what period men began to sail by the stars, or who were the first people that did so, is not clear; but the honor is usually given to the Phœnicians. That it was practiced by the Greeks, as early as the time of the Trojan war, that is, about 1200 years B. C., we learn from Homer; for he says of Ulysses, when sailing on his raft, that

"Placed at the helm he sate, and mark'd the skies,
Nor closed in sleep his ever watchful eyes."

It is rational to suppose that the stars were first used as a guide to travellers by land, for we can scarcely imagine that men would venture themselves upon the sea by night, before they had first learned some safe and sure method of directing their course by land. And we find, according to Diodorus Siculus, that travellers in the sandy plains of Arabia were accustomed to direct their course by *the Bears*.

That people travelled in these vast deserts at night by observing the stars, is directly proved by this passage of the Koran:—"God has given you the stars, to be guided in the dark, both by land and by sea."

TELESCOPIC OBJECTS.

1. α Ursa Majoris (*Dubhe, one of the pointers*)—A fine star with a distant companion; R. A. 10h. 53m. 48s.; Dec. N. 62° 36′ 8″. A 1½, yellow; B 8, yellow.

2. β Ursa Majoris (*Merak*)—A bright star with a distant companion; R. A. 10h. 52m. 08″; Dec. N. 57° 14′ 2″. A 2, greenish white; B 11, pale grey—other stars in field.

3. γ Ursa Majoris (*Phad*)—A star with a distant companion; R. A. 11h. 45m. 23s.; Dec. N. 54° 35′ 1″. A 2, topaz yellow; B 9, ashy paleness, with a fine group of stars in the field.

4. δ Ursa Majoris (*Megrez*)—A fine star, suspected of variability, with a distant companion; R. A. 12h. 07m. 28s.; Dec. N. 57° 55′ 3″. A 3, pale yellow; B 9, ash colored, with other stars in field.

5. ζ Ursa Majoris (*Mizar.*)—A splendid double star in the middle of the tail; R. A. 13h. 17m. 28s.; Dec. N. 55° 45′ 8″. A 3, brilliant white; B 5, pale emerald. Alcor and other stars in the field. Map VIII. Fig. 7.

Telescopic Objects.—Alpha? Beta? Gamma? Delta? Zeta? Eta? Iota? Nu? What nebula? Which shown on the map?

6. η URSA MAJORIS (*Benetnasch*)—A DOUBLE STAR in the tip of the tail; R. A. 13h. 41m. 14s.; Dec. N. 50° 06′ 5″. A 2½, brilliant white; B 9, dusky.

7. ι URSA MAJORIS (*Al Kaphrah*)—A DOUBLE STAR in the right fore paw; R. A. 8h. 48m. 14s.; Dec. N. 48° 39′ 9″. A 3½, topaz yellow; B 13, purple. Sir J. Herschel supposed A might be a satellite, shining only by reflection.

8. ν URSA MAJORIS—A delicate DOUBLE STAR in the left hind foot, just above ξ or El Acola; R. A. 11h. 09m. 49s.; Dec. N. 30° 58′ 0′. A 4, orange tint; B 12, cornelian blue; a close but elegant object.

9. A beautiful PLANETARY NEBULA, just south of β; R. A. 10h. 28m. 45s.; Dec. N. 54° 20′ 4″. A small, well defined object, bluish white, and brightens towards the center.

10. A BRIGHT NEBULA in the right fore leg; R. A. 9h. 10m. 54s.; Dec. N. 51° 40′ 5″. Of a pale creamy whiteness, with several bright stars in the northern part of the field. Nebula large, elliptical and nucleated.

11. A bright-class ROUND NEBULA above the Bear's ear; R. A. 9h. 34m. 32s.; Dec. N. 73° 01′ 2″. Several stars in field, of 9th to 12th magnitude.

12. A FINE OVAL NEBULA in the ear; R. A. 9h. 42m. 10s.; Dec. N. 69° 51′ 8″.

13. A LARGE MILK-WHITE NEBULA on the body, about 1° south of β or Merak; R. A. 11h. 02m. 02s.; Dec. N. 56° 31′ 8″.

14. A LARGE PLANETARY NEBULA on the flank, with several stars in the field, one of which is pretty close; R. A. 11h. 05m. 24s.; Dec. N. 55° 52′ 9″. About 2° to the S. E. of β, and just south of a line from β to γ; a singular object, circular, uniform, and seemingly of the size of Jupiter. W. Herschel assigned this object to the 980th order of distance. Map VIII., Fig. 42.

15. A BRIGHT-CLASS NEBULA in a poor field, behind the left hind leg, one-third the distance from δ towards Denebola; R. A. 11h. 58m. 51s.; Dec. N. 43° 57′ 3″. Of a lucid white, various and elongated. Map VIII., Fig. 43.

16. A LARGE WHITE NEBULA near the haunches; R. A. 12h. 11m. 04s.; Dec. N. 48° 11′ 1″. A noble-sized oval, with a bright nucleus, the lateral edges better defined than the ends. Found by running a diagonal line across the square, from α through γ, and about 7½° beyond, into the S. E.

COMA BERENICES (BERENICE'S HAIR).—MAP IV.

152. This is a beautiful cluster of small stars, situated about 5° E. of the equinoctial colure, and midway between Cor Caroli on the northeast, and Denebola on the southwest. If a straight line be drawn from Benetnasch through Cor Caroli, and produced to Denebola, it will pass through it.

153. The principal stars are of between the 4th and 5th magnitudes. According to Flamsted, there are thirteen of the 4th magnitude, and according to others there are seven; but the student will find agreeably to his map, that there is apparently but *one* star in this group, entitled to that rank, and this is situated about 7° S. E. of the main cluster.

Although it is not easy to mistake this group for any other in the same region of the skies, yet the stars which compose it are all so small as to be rarely distinguished in the full presence of the moon. The confused lustre of this assemblage of small stars somewhat resembles that of the Milky Way.

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152. Describe Coma Berenices? How find it? 153. Its principal stars, their number &c.? What remark in fine print?

154. The whole number of stars in this constellation is 43; its mean right ascension is 185°. It consequently is on the meridian the 13th of May.

> ———————"Now behold
> The glittering maze of *Berenice's Hair;*
> *Forty* the stars; but such as seem to kiss
> The *flowing tresses* with a lambent fire,
> Four to the telescope alone are seen."

HISTORY.

Berenice was of royal descent, and a lady of great beauty, who married Ptolemy Soter, or Evergetes, one of the kings of Egypt, her own brother, whom she loved with much tenderness. When he was going on a dangerous expedition against the Assyrians, she vowed to dedicate her hair to the goddess of beauty, if he returned in safety. Some time after the victorious return of her husband, Evergetes, the locks, which, agreeably to her oath, she had deposited in the temple of Venus, disappeared. The king expressed great regret at the loss of what he so much prized; whereupon Conon, his astronomer, publicly reported that Jupiter had taken away the queen's locks from the temple and placed them among the stars.

> "There *Berenice's locks* first rose so bright,
> The heavens bespangling with dishevelled light."

Conon being sent for by the king, pointed out this constellation, saying, "There behold the locks of the queen." This group being among the unformed stars until that time, and not known as a constellation, the king was satisfied with the declaration of the astronomer, and the queen became reconciled to the partiality of the gods.

Callimachus, a historian and poet, who flourished long before the Christian era, has these lines as translated by Tytler:—

> "Immortal Conon, blest with skill divine,
> Amid the sacred skies behold me shine:
> E'en me, the *beauteous hair*, that lately shed
> Refulgent beams from *Berenice's* head;
> The *lock* she fondly vowed with lifted arms,
> Imploring all the powers to save from harms
> Her dearer lord, when from his bride he flew,
> To wreak stern vengeance on the Assyrian crew."

TELESCOPIC OBJECTS.

1. A TRIPLE STAR, between the tresses and Virgo's northern wing; R. A. 12h. 45m. 25s., Dec. N. 22° 07′ 0″. A 5, pale yellow; B, indistinct; C 10, cobalt blue. About 7° south-east of α Berenices, and 20° west of Arcturus.

2. A GLOBULAR CLUSTER, between the tresses and the Virgin's left hand, with a coarse pair and one single star in the field; R. A. 11h. 05m. 03s.; Dec. N. 19° 01′ 3″. A brilliant mass of minute stars from the 11th to the 15th May; compressed at center. A line through δ and ε Virginis, northward, meeting another from Arcturus over η Bootes, falls upon this magnificent object.

3. A CONSPICUOUS NEBULA between the tresses and the virgin's left arm; R. A. 12h. 48m. 52s.; Dec. N. 22° 33′ 2″. A magnificent object, both in size and brightness, with several small stars in the field. Elongated, compressed in the centre, and was likened by Sir Charles Blagdon to a "*black eye*." Map VIII., Fig. 44.

CORVUS (THE CROW).—MAP IV.

155. This small constellation is situated on the eastern part of Hydra, 15° E of the Cup, and is on the same meridian with

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154. What number of stars?
HISTORY.—Who was Berenice? Story of the loss of her hair, &c.?
TELESCOPIC OBJECTS.—What triple stars? Cluster? Nebula? Point out on the Map.
155. Where is Corvus situated? Number of visible stars?

Coma Berenices, but as far S. of the equinoctial as Coma Berenices is N. of it. It therefore culminates at the same time, on the 12th of May. It contains nine visible stars, including three of the 3d magnitude, and two of the 4th.

156. This constellation is readily distinguished by means of three stars of the 3d magnitude and one of the 4th, forming a trapezium or irregular square, the two upper ones being about $3\frac{1}{2}°$ apart, and the two lower ones 6° apart.

157. The brightest of the two upper stars, on the left, is called *Algorab*, and is situated in the E. wing of the Crow; it has nearly the same declination S. that the Dog Star has, and is on the meridian about the 13th of May. It is $21\frac{1}{2}°$ E. of Alkes in the Cup, $14\frac{1}{2}°$ S. W. of Spica Virginis, a brilliant star of the 1st magnitude, to be described in the next chapter.

158. *Beta*, on the back of Hydra, and in the foot of the Crow, is a star of the 3d magnitude, nearly 7° S. of Algorab. It is the brightest of the two lower stars, and on the left. The right-hand lower one is a star of the 4th magnitude, situated in the neck, marked *Epsilon*, about 6° W. of Beta, and may be known by a star of the same magnitude situated 2° below it, in the eye, and called *Al Chiba*. Epsilon is $21\frac{2}{3}°$ S. of the vernal equinox, and if a meridian should be drawn from the pole through Megrez, and produced to Epsilon Corvi, it would mark the equinoctial colure.

159. *Gamma*, in the W. wing, is a star of the 3d magnitude, $3\frac{1}{2}°$ W. of Algorab, and is the upper right-hand one in the square. It is but 1° E. of the equinoctial colure.

10° E. of Beta is a star of the 3d magnitude, in the tail of Hydra, marked *Gamma*; these two, with Algorab, form nearly a right-angled triangle, the right angle being at Beta.

HISTORY.

The Crow, it is said, was once of the purest white, but was changed for tale-bearing to its present color. A fit punishment for such a fault.

> "The raven once in snowy plumes was drest,
> White as the whitest dove's unsullied breast,
> Fair as the guardian of the capitol,
> Soft as the Swan; a large and lovely fowl;
> His tongue, his prating tongue, had changed him quite,
> To sooty blackness from the purest white."

According to Greek fable the Crow was made a constellation by Apollo. This god being jealous of Coronis (whom he tenderly loved), the daughter of Phlegyas and

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156. How is it found? 157. What said of Algorab? 158. Of Beta? Epsilon? Al Chiba? What said of the Pole, Megrez, and Epsilon? 159. Of Gamma? What triangle?

HISTORY.—Story of the original color of Corvus? Greek fable of the origin of the constellation? What other account?

mother of Æsculapius, sent a crow to watch her behavior; the bird perceived her criminal partiality for Ischys the Thessalian, and immediately acquainted Apollo with her conduct, which so fired his indignation that he lodged an arrow in her breast, and killed her instantly.

"The god was wroth; the color left his look,
The wreath his head, the harp his hand forsook:
The silver bow and feathered shafts he took,
And lodged an arrow in the tender breast,
That had so often to his own been prest."

To reward the crow, he placed her among the constellations.

Others say that this constellation takes its name from the daughter of Coronæus, king of Phocis, who was transformed into a crow by Minerva, to rescue the maid from the pursuit of Neptune. The following, from an eminent Latin poet of the Augustan age, is her own account of the metamorphosis as translated into English verse by Mr. Addison:—

"For as my arms I lifted to the skies,
I saw black feathers from my fingers rise;
I strove to fling my garment on the ground;
My garment turned to plumes, and girt me round;
My hands to beat my naked bosom try;
Nor naked bosom now, nor hands had I·
Lightly I tripp'd, nor weary as before
Sunk in the sand, but skimm'd along the shore;
Till, rising on my wings, I was preferr'd
To be the chaste Minerva's virgin bird"

TELESCOPIC OBJECTS.

1. β Corvi—A fine bright star nearly midway between two distant companions. A 2½, ruddy yellow; B 7, greenish yellow; C 8, dull grey. β is actually the lucida, or brightest star of the constellation.

2. δ Corvi—A double star in the right wing; R. A. 12h. 21m. 35s.; Dec. S. 15° 37′ 04″. A 3, pale yellow; B 8½, purple.

VIRGO (the virgin).—MAP IV.

160. This is the sixth sign, and seventh constellation in the ecliptic. It is situated next east of Leo, and about midway between Coma Berenices on the N. and Corvus on the S. It occupies a considerable space in the heavens, and contains, according to Flamsted, one hundred and ten stars, including one of the 1st, six of the 3d, and ten of the 4th magnitudes. Its mean declination is 5° N., and its mean right ascension is 195°. Its center is therefore on the meridian about the 23d of May.

The sun enters the *sign* Virgo, on the 23d of August, but does not enter the *constellation* before the 15th of September. When the sun is in this sign, the earth is in Pisces; and *vice versa*.

161. *Alpha*, or *Spica Virginis*, in the ear of corn which the virgin holds in her left hand, is the most brilliant star in this constellation, and situated nearly 15° E. N. E. of Algorab in the Crow, about 35° S. E. of Denebola, and nearly as far S. S.

Telescopic Objects.—Beta? Delta?
160. Order and position of Virgo? Extent? Number of stars? Magnitudes? Mean declination of Virgo? Remark in fine print? 161. What said of Alpha, or Spica Vir-

W. of Arcturus—three very brilliant stars of similar magnitude that form a large equilateral triangle, pointing to the S. Arcturus and Denebola are also the base of a similar triangle on the north, terminating in Cor Caroli, which, joined to the former, constitutes the *Diamond of Virgo.*

162. The length of this figure, from Cor Caroli, on the north, to Spica Virginis on the south, is 50°. Its breadth, or shorter diameter, extending from Arcturus on the east to Denebola on the west, is $35\frac{1}{2}$°. Spica may otherwise be known by its solitary splendor, there being no visible star near it except one of the 4th magnitude, situated about 1° below it, on the left.

The position of this star in the heavens, has been determined with great exactness for the benefit of navigators. It is one of the stars from which the moon's distance is taken for determining the longitude at sea. Its situation is highly favorable for this purpose, as it lies within the moon's path, and little more than 2° below the earth's orbit.

Its right ascension being 199°, it will come to our meridian at 9 o'clock about the 28th of May, in that point of the heavens where the sun is at noon about the 20th of October.

163. *Beta*, called also *Zavijava*, is a star of the 3d magnitude, in the shoulder of the wing, $7\frac{1}{3}$° W. of Eta, with which and Gamma it forms a line near the Earth's orbit, and parallel to it. Beta, Eta, Gamma and Spica, form the lower and longer side of a large spherical triangle whose vertex is in Beta.

164. *Vindemiatrix*, is a star of the 3d magnitude, in the right arm, or northern wing of Virgo, and is situated nearly in a straight line with, and midway between Coma Berenices and Spica Virginis. It is $19\frac{1}{2}$° S. W. of Arcturus, and about the same distance S. E. of Coma Berenices, and forms with these two a large triangle, pointing to the south. It bears also 18° S. S. E. of Denebola, and comes to the meridian about 23 minutes before Spica Virginis.

165. *Zeta*, is a star of the 3d magnitude, $11\frac{1}{2}$° N. of Spica, and very near the equinoctial. *Gamma*, situated near the left side, is also a star of the 3d magnitude, and very near the equinoctial. It is 13° due west of Zeta, with which and Spica it forms a handsome triangle. *Eta*, is a star of the 3d magnitude in the southern wing, 5° W. of Gamma, and but $2\frac{1}{2}$° E. of the autumnal equinox.

The other stars in this figure may be easily traced by means of the map. About 13° E. of Spica, there are two stars of the 4th magnitude, 3° apart, which mark the foot of Virgo. These two stars are on nearly the same meridian with Arcturus, and culminate nearly at the same time. The lower one, marked *Lambda*, is on the south, and but 8° W. of the principal star in Libra. Several other stars of the 3d magnitude lie scattered about in this constellation, and may be traced out by the map.

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ginis? Diamond? 162. Length of Virgo? Breadth? How may Spica be known? Note in fine print? 163. Describe Beta? What triangle? 164. Vindematrix? 165. Zeta, Gamma and Eta? What other stars and how found?

"Her lovely tresses glow with starry light;
Stars ornament the bracelet on her hand;
Her vest in ample fold, glitters with stars:
Beneath her snowy feet they shine; her eyes
Lighten, all glorious, with the heavenly rays,
But *first* the star which crowns the golden sheaf."

HISTORY.

According to the ancient *poets*, this constellation represents the Virgin Astræa, the goddess of justice, who lived upon the earth during the golden age; but being offended at the wickedness and impiety of mankind during the brazen and iron ages of the world, she returned to heaven, and was placed among the constellations of the zodiac, with a pair of scales (Libra) in one hand and a sword in the other.

Hesiod, who flourished nearly a thousand years before the birth of our Saviour, and later writers, mention four ages of the world; the golden, the silver, the brazen, and the iron age. In the beginning of things, say they, all men were happy, and all men were good; the earth brought forth her fruits without the labor of man; and cares, and wants, wars and diseases, were unknown. But this happy state of things did not last long. To the golden age, the silver age succeeded; to the silver the brazen; and to the brazen, the iron. Perpetual spring no longer reigned; men continually quarreled with each other; crime succeeded to crime; and blasphemy and murder stained the history of every day. In the golden age, the gods did not disdain to mix familiarly with the sons of men. The innocence, the integrity and brotherly love which they found among us, were a pleasing spectacle even to superior natures; but as mankind degenerated, one god after another deserted their late beloved haunts; Astræa lingered the last; but finding the earth steeped in human gore, she herself flew away to the celestial regions.

"Victa jacet pietas; et virgo cæde madentes
Ultima cœlestum terras Astræa reliquit."
Met. Lib. i. v. 149.

"Faith flees, and piety in exile mourns;
And *justice* here oppress'd, to heaven returns."

Some, however, maintain, that Erigone was changed into the constellation Virgo. The death of her father Icarus, an Athenian, who perished by the hands of some peasants, whom he had intoxicated with wine, caused a fit of despair, in which Erigone hung herself; and she was afterward, as it is said, placed among the signs of the zodiac. She was directed by her faithful dog Mæra to the place where her father was slain. The first bough on which she hung herself breaking, she sought a stronger, in order to effect her purpose.

"Thus once in Marathon's impervious wood,
Erigone beside her father stood,
When hastening to discharge her pious vows,
She loos'd the knot, and cull'd the strongest boughs."
LEWIS' Statius, B. xi.

The famous zodiac of Dendera, as we have already noticed, commences with the sign Leo; but another zodiac, discovered among the ruins at Esne, in Egypt, commences with Virgo; and from this circumstance, some have argued, that the regular precession of the equinoxes established a date to this at least 2000 years older than that at Dendera. The discoveries of Champollion, however, render it probable that this ancient relic of astrology at Esne was erected during the reign of the Emperor Claudius, and consequently did not precede the one at Dendera more than fourteen years.

Of this, however, we may be certain: the autumnal equinox now corresponds with the first degree of *Virgo;* and, consequently, if we find a zodiac in which the summer solstice was placed where the autumnal equinox now is, that zodiac carries us back 90° on the ecliptic; this divided by the annual precision 50¼″ must fix the date at about 6450 years ago. This computation, according to the chronology of the Sacred writings, carries us back to the earliest ages of the human species on earth, and proves, at least, that astronomy was among the first studies of mankind. The most rational way of accounting for this zodiac, says Jamieson, is to ascribe it to the family of Noah; or perhaps to the patriarch himself, who constructed it for the benefit of those who should live after the deluge, and who preserved it as a monument to perpetuate the actual state of the heavens immediately subsequent to the creation.

HISTORY.—Account of the poets? Hesiod's account? What other supposition? What zodiacs mentioned, and what calculations, &c.?

TELESCOPIC OBJECTS.

1. α Virginis (*Spica*)—A splendid star with a minute companion; R. A. 13h. 16m. 47s.; Dec. S. 10° 19′ 5″. A 1, brilliant flushed white; B 10, bluish tinge.

2. β Virginis (*Zarijan*)—A bright star with a small companion; R. A. 11h. 42m. 22s.; Dec. N. 2° 40′ 0″. A 3½, pale yellow; B 11, light blue.

3. γ Virginis—A fine binary star in the Virgin's right side; R. A. 12h. 33m. 33s.; Dec. S. 0° 34′ 3″. A 4, silvery white; B 4, pale yellow. A Binary System with a period of about 157 years. Map. VIII. Fig. 8.

4. δ Virginis—A star with a distant companion, on the left side, about 17° north-northwest of Spica, and nearly midway between γ and ε Virginis; R. A. 12h. 47m. 33s.; Dec. N. 4° 16′ 1″. A 3½, golden yellow; B 10½, reddish; several small stars in the field.

5. ε Virginis (*Vendemiatrix*)—A star with a minute distant companion, on the upper extremity of the Virgin's left wing; R. A. 12h. 54m. 13s.; Dec. 11° 49′ 03″. A 3½, bright yellow; B 15, intense blue. This last color on so small an object is very striking.

6. A triple star in the lower part of the southern wing, 7° northwest of Spica; R. A. 13h. 01m. 40s.; Dec. S. 4° 41′ 0″. A 4½, pale white; B 9, violet; C 10, dusky.

7. A large, but rather pale nebula, between Virgo's left wing and Leo's tail; R. A. 12h. 06m. 01s.; Dec. N. 15° 47′ 02″. About 6½° from β Leonis, towards Arcturus, on the outskirts of a vast region of Nebula in the Virgin's wing. It is elongated in the direction of two telescopic stars.

8. A long pale-white nebula, among telescopic stars, on the upper part of the Virgin's left wing; R. A. 12h. 07m. 37s.; Dec. N. 14° 02′ 08″. Situated one-third of the way from β Leonis to ε Virginis, on the border of the vast nebulous region in Virgo. A curious object in the shape of a weaver's shuttle.

9. A lucid white elliptical nebula, between the Virgin's right elbow and the Crow; R. A. 12h. 31m. 40s.; Dec. S. 10° 43′ 07″. Map VIII., Fig. 45.

10. A double nebula in the center of Virgo's left wing; R. A. 12h. 35m. 33s.; Dec. N. 12° 26′ 01″. It is 5° west of Vendemiatrix, toward Regulus, in a wonderful nebulous region. Map VIII., Fig. 46, shows it on the right, with two other nebulæ, and several stars in the figure.

11. A pale elliptical nebula, in the middle of the left wing; R. A. 12h. 44m. 50s., Dec. N. 12° 05′ 09″. It looks like a paper *kite*, under an arch formed by three telescopic stars. Map. VIII., Fig. 47.

12. A wonderful nebulous region, about 2½° from north to south, and 3° from east to west, is found on the left wing. It includes several of the objects described. For a drawing of this remarkable field, see Map VIII., Fig. 48.

CANES VENATICI (the greyhounds).—MAP IV.

166. This modern constellation, embracing two in one, was made by Hevelius out of the unformed stars of the ancients which were scattered between Bootes on the east, and Ursa Major on the west, and between the handle of the Dipper on the north, and Coma Berenices on the south.

These Hounds are represented on the celestial sphere as being in pursuit of the Great Bear, which Bootes is hunting round the pole of heaven, while he holds in his hand the leash by which they are fastened together. The northern one is called *Asterion*, and the southern one, *Chara*.

Telescopic Objects.—Alpha? Beta? Gamma? Delta? Epsilon? What triple star? Nebula? Point out on the map.

166. Situation of Canes Venatici? By whom formed? How represented? Names of the hounds?

167. The stars in this group are considerably scattered, and are principally of the 5th and 6th magnitudes; of the twenty-five stars which it contains, there is but one sufficiently large to engage our attention. *Cor Caroli* or *Charles' Heart*, so named by Sir Charles Scarborough, in memory of King Charles the First, is a star of the 3d magnitude, in the neck of Chara, the southern Hound.

When on the meridian, Cor Caroli is 17½° directly S. of Alioth, the third star in the handle of the Dipper, and is so nearly on the same meridian that it culminates only one minute and a half after it. This occurs on the 20th of May.

A line drawn from Cor Caroli through Alioth will lead to the N. polar star. This star may also be readily distinguished by its being in a straight line with, and midway between Benetnasch, the first star in the handle of the Dipper, and Coma Berenices; and also by the fact that when Cor Caroli is on the meridian, Denebola bears 28° S. W. and Arcturus 26° S. E. of it, forming with these two stars a very large triangle, whose vertex is at the north; it is also at the northern extremity of the large Diamond already described.

The remaining stars in this constellation are too small and too much scattered to excite our interest.

TELESCOPIC OBJECTS.

1 A DOUBLE STAR near Chara's mouth; R. A. 12h. 08m. 06s.; Dec. N. 41° 33′ 01″. A 6, yellow; B 9, blue. It is about 9° south of Cor Caroli, and one-third of the distance between that star and δ Leonis. Map VIII., Fig. 10.

2. A MAGNIFICENT CLUSTER, between the southern Hound and the knee of Bootes; R. A. 13h. 34m. 45s. A splendid group, supposed to contain not less than 1,000 stars. Map VIII., Fig. 49.

3. A PAIR OF LUCID WHITE NEBULÆ, near the ear of the northern Hound; R. A. 13h. 23m. 06s.; Dec. N. 48″ 01′ 07″.

4. A LARGE BRIGHT NEBULA, 2½° north by west of Cor Caroli; R. A. 12h. 43m. 22s.; Dec. N. 41° 59′ 07″. A fine pale-white object, compressed toward the center, and with several small stars in the field.

CHAPTER VIII.

CONSTELLATIONS ON THE MERIDIAN IN JUNE.

BOOTES (THE BEAR DRIVER).—MAP IV.

168. THE BEAR-DRIVER is represented by the figure of a huntsman in a running posture, grasping a club in his right hand, and holding up in his left the leash of his two greyhounds, Asterion and Chara, with which he seems to be pursuing the Great Bear round the pole of the heavens. He is thence called Arctophylax, or the "Bear-Driver."

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167. Describe the stars in this group? Cor Caroli?

TELESCOPIC OBJECTS.—What double star? Show on the map? Clusters? Point out on the map? Nebulæ?

168 Describe Bootes? Why called the Bear-Driver?

169. This constellation is situated between Corona Borealis on the east, and Cor Caroli, or the Greyhounds, on the west. It contains fifty-four stars, including one of the 1st magnitude, seven of the 3d, and ten of the 4th. Its mean declination is 20° N., and its mean right ascension is 212° ; its center is therefore on the meridian the 9th of June. It may be easily distinguished by the position and splendor of its principle star, *Arcturus*, which shines with a reddish luster, very much resembling that of the planet Mars.

170. *Arcturus* is a star of the 1st magnitude, situated near the left knee, 26° S. E. of Cor Caroli and Coma Berenices, with which it forms an elongated triangle, whose vertex is at Arcturus. It is 35½° E. of Denebola, and nearly as far N. of Spica Virginis, and forms with these two, as has already been observed, a large equilateral triangle. It also makes, with Cor Caroli and Denebola, a large triangle whose vertex is in Cor Caroli.

A great variety of geometrical figures may be formed of the stars in this bright region of the skies. For example: Cor Caroli on the N., and Spica Virginis on the S., constitute the extreme points of a very large figure in the shape of a diamond; while Denebola on the W. and Arcturus on the E., limit the mean diameter at the other points.

171. Arcturus is supposed by some to be nearer the Earth than any other star in the northern hemisphere.

Five or six degrees S. W. of Arcturus are three stars of the 3d and 4th magnitudes, lying in a curved line, about 2° apart, and a little below the left knee of Bootes; and about 7° E. of Arcturus are three or four other stars of similar magnitude, situated in the other leg, making a larger curve N. and S.

172. *Mirac*, in the girdle, is a star of the 3d magnitude, 10° N. N. E. of Arcturus, and about 11½° W. of Alphacca, a star in the Northern Crown. *Seginus*, in the west shoulder, is a star of the 3d magnitude, nearly 20° E. of Cor Caroli, and about the same distance N. of Arcturus, and forms with these two, a right-angled triangle, the right angle being at Seginus. The same star forms a right-angled triangle with Cor Caroli and Alioth, in Ursa Major, the right angle being at Cor Caroli.

173. *Alkaturops*, situated in the top of the club, is a star of the 4th magnitude, about 10½° in an easterly direction from Seginus, which lies in the left shoulder; and about 4½° S. of Alkaturops is another star of the 4th magnitude, in the club, near the east shoulder, marked *Delta*. Delta is about 9° distant from Mirac, and 7½° from Alphacca, and forms, with these two, a regular triangle.

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169. How situated? How many stars, and their magnitude? Declination? How distinguished? 170. Describe Arcturus, and its position? What triangles? What diamond? 171. Supposed nearness of Arcturus? 172. Describe Mirac and Seginus? What triangles? 173. Situation and magnitude of Alkaturops? Of Delta?

174. *Nekkar* is a star of the 3d magnitude, situated in the head, and is about 6° N. E. of Seginus, and 5° W. of Alkaturops; it forms, with Delta and Seginus, nearly a right angled triangle, the right angle being at Nekar.

These are the principal stars in this constellation, except the three stars of the 4th magnitude situated in the right hand. These stars may be known by two of them being close together, and about 5° beyond Benetnasch, the first star in the handle of the Dipper. About 6° E. of Benetnasch is another star of the 4th magnitude, situated in the arm which forms, with Benetnasch and the three in the hand, an equilateral triangle.

175. The three stars in the left hand of Bootes, the first in the handle of the Dipper, Cor Caroli, Coma Berenices, and Denebola, are all situated nearly in the same right line, running from northeast to southwest.

"Bootes follows with redundant light;
Fifty-four stars he boasts; one guards the Bear,
Thence call'd *Arcturus*, of resplendent front,
The pride of the *first order:* eight are veil'd,
Invisible to the unaided eye."

Manilius thus speaks of this constellation :—

"And next Bootes comes, whose order'd beams
Present a figure driving of his teams.
Below his girdle, near his knees, he bears
The bright *Arcturus*, fairest of the stars."

176. Arcturus is mentioned by name in that beautiful passage in Job, already referred to, where the Almighty answers "out of the whirlwind," and says :—

"Canst thou the sky's benevolence restrain,
And cause the Pleiades to shine in vain?
Or, when Orion sparkles from his sphere,
Thaw the cold seasons and unbind the year?
Bid Mazzaroth his wonted station know,
And teach the bright *Arcturus* where to glow?"

Young's Paraphrase.

HISTORY.

The ancient Greeks called this constellation Lycaon—a name derived from λυκος, which signifies a *wolf.* The Hebrews called it *Caleb Anubach*, the "Barking Dog;" while the Latins, among other names, called it *Canis.* If we go back to the time when Taurus opened the year, and when Virgo was the fifth of the zodiacal signs, we shall find that brilliant star Arcturus, so remarkable for its red and fiery appearance, corresponding with a period of the year as remarkable for its heat. Pythagoras, who introduced the true system of the universe into Greece, received it from Œnuphis, a priest of On, in Egypt. And this college of the priesthood was the noblest of the east, in cultivating the studies of philosophy and astronomy. Among the high honors which Pharaoh conferred on Joseph, he very wisely gave him in marriage "a daughter of the priest of On." The supposed era of the book of Job, in which *Arcturus* is repeatedly mentioned, is 1513 B. C.

Bootes is supposed by some to be Icarus, the father of Erigone, who was killed by shepherds for intoxicating them. Others maintain that it is Erichthonius, the inventor of chariots. According to Grecian fable, as well as later authorities, Bootes was the son of Jupiter and Calisto, and named Arcas. Ovid relates, that Juno, being incensed at Jupiter for his partiality to Calisto, changed her into a bear, and that her son Arcas, who became a famous hunter, one day roused a bear in the chase, and not knowing that it

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174. Of Nekkar? Any other stars? 175. What said of three stars in the hand of Bootes? 176. What star in Bootes mentioned in the Scriptures? Poetic quotation? History.—Greek name of this constellation? Hebrew? Grecian fable? Ovid's

was his mother, was about to kill her, when Jupiter snatched them both up to heaven and placed then among the constellations. Met. b. ii. v. 496–508.

"But now her son had fifteen summers told,
Fierce at the chase, and in the forest bold;
When as he beat the woods in quest of prey,
He chanced to rouse his mother where she lay.
She knew her son, and kept him in her sight,
And fondly gazed: the boy was in a fright,
And aim'd a pointed arrow at her breast;
And would have slain his mother in the beast:
But Jove forbade, and snatch'd them through the air
In whirlwinds up to heaven, and fix'd 'em there;
Where the new constellations nightly rise,
And add a luster to the northern skies."
Garth's Translation.

LUCAN, in his *Pharsalia*, says—

"That Brutus, on the busy times intent,
To virtuous Cato's humble dwelling went,
'Twas when the solemn dead of night came on,
When bright *Calisto, with her shining son,*
Now half that circle round the pole had run."

This constellation is called *Bootes*, says Cicero (*Nat. Deo. Lib. ii.* 42), from a Greek word signifying a wagoner, or ploughman; and sometimes *Arctophylax* from two Greek words signifying bear-keeper or bear-driver.

"Arctophylax, vulgo qui dicitur esse Bootes,
Quod quasi temone adjunctum præ se quatit Arctum."

The stars in this region of the skies seem to have attracted the admiration of almost all the eminent writers of antiquity. Claudian observes, that

"Bootes with his wain the north unfolds;
The southern gate Orion holds."

And Aratus, who flourished nearly 800 years before Claudian, says,

"Behind, and seeming to urge on the Bear,
Arctophylax, on earth Bootes named,
Sheds o'er the Arctic car his silver light."

This is the poet whom St. Paul refers to when he tells the Athenians, Acts xvii. 28, that "some of their own poets have said, 'Του γαρ και γενος εσμεν:' For we are also his offspring." These words are the beginning of the 5th line of the "Phenomena" of Aratus, a celebrated Greek poem written in the reign of Ptolemy Philadelphus, two thousand one hundred years ago, and afterward translated into Latin verse by Cicero. Aratus was a poet of St. Paul's own country. The apostle borrows again from the same poet, both in his Epistle to the Galatians, and to Titus. The *subject* of the poem was grand and interesting: hence we find it referred to in the writings of St. Clement, St. Jerome, St. Chrysostom, Œcumenius, and others. As this poem describes the nature and motions of the stars, and the origin of the constellations, and is, moreover, one of the oldest compositions extant upon this interesting subject, the author has taken some pains to procure a Polyglot copy *from Germany*, together with the *Astronomicon* of Manilius, and some other works of similar antiquity, that nothing should be wanting on his part which could impart an interest to the study of the constellations, or illustrate the frequent allusions to them which we meet with in the Scriptures.

Dr. Doddridge says of the above quotation, that "these words are well known to be found in Aratus, a poet of Paul's own country, who lived almost 300 years before the apostle's time; and that the same words, with the alteration of only one letter, are to be found in the *Hymn of Cleanthes*, to Jupiter, the *Supreme God;* which is, beyond comparison, the purest and finest piece of *natural religion*, of its length, which I know in the whole world of Pagan antiquity; and which, so far as I can recollect, contains nothing unworthy of a Christian, or, I had almost said, of an inspired pen. The apostle might perhaps refer to *Cleanthes*, as well as to his countryman Aratus."

Many of the elements and fables of heathen mythology are so blended with the

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account? Lucan and Cicero? Claudian? Aratus? Who was Aratus? What remarkable quotation? Remark of Doddridge? What other passage cited by St. Paul? From whom?

inspired writings, that they must needs be studied, more or less, in order to have a more proper understanding of numerous passages both in the Old and New Testament.

The great apostle of the Gentiles, in uttering his inspired sentiments, and in penning his epistles, often refers to and sometimes quotes verbatim from the distinguished writers who preceded him.

Thus, in 1 Cor. xv. 33, we have "Μη πλανασθε· 'Φθειρουσιν ηθη χρησθ' ομιλιαι κακαι.' Be not deceived; evil communications corrupt good manners;" which is a literal quotation by the apostle from the Thais of Menander, an inventor of Greek comedy, and a celebrated Athenian poet, who flourished nearly 400 years before the apostle wrote his epistle to the Corinthians. Thus Paul adopts the sentiment of the comedian, and it becomes hallowed by "the divinity that stirred within him." Tertullian remarks, that "in quoting this, the apostle hath sanctified the poet's sentiment."

TELESCOPIC OBJECTS.

1. α Boötis (*Arcturus*)—A DOUBLE STAR; R. A. 14h. 08m. 22s.; Dec. N. 20° 00′ 9″. A 1, reddish yellow; B 11, lilac.

2. β Boötis (*Nekkar*)—A star with a distant companion in the head of the figure; R. A. 14h. 55m. 55s.; Dec. N. 41° 01′ 5″. A 3, golden yellow: B 11, pale grey.

3. δ Boötis—A star with a distant companion in the left shoulder; R. A. 15h. 09m. 03s.; Dec. N. 33° 54′ 9″. A 3½, pale yellow; B 8½, light blue.

4. ε Boötis (*Mirac*)—A DOUBLE STAR in the left hip; R. A. 14h. 38m. 00s.; Dec. N. 27° 45′ 1″. A 3, pale orange; B 7, sea green. A lovely object—colors distinct, and strongly contrasted.

5. ζ Boötis—A close DOUBLE STAR on the left leg; R. A. 14h. 33m. 31s.; Dec. N. 14° 25′ 1″. A 3½, bright white; B 4½, bluish white.

6. η Boötis (*Mufride*)—A star with a distant companion on the right leg; R. A. 13h. 47m. 04s.; Dec. N. 19° 12′ 0″. About 5½° west by south of Arcturus. A 3, pale yellow; B 10½, lilac.

7. ι Boötis—A DELICATE TRIPLE STAR in the right hand (Map VI.); R. A. 14h. 10m. 30s.; Dec. N. 52° 06′ 4″. A and B 4½, pale yellow; C 8, creamy white.

8. ξ Boötis—A BINARY STAR on the left knee; R. A. 14h. 44m. 00s.; Dec. N. 19° 46′ 1″. A 3½, orange; B 6½, purple. Supposed period 400 years.

9. A RICH GROUP of stars in the vicinity of Arcturus, and surrounding that star. May be seen with small telescopes. Map VIII., Fig. 50.

10. A PALE WHITE NEBULA in a nebulous field, 5° north northeast of *Alkaid*; R. A. 13h. 57m. 31s.; Dec. N. 55° 08′ 3″. About 5° southeast of *Mizar*. A difficult object except with a good instrument.

11. A WHITE ROUND NEBULA near the right shoulder; R. A. 14h. 11m. 44s.; Dec. N. 37° 14′ 4″. Pale, except at the center—telescopic stars in the field.

NOCTA (THE OWL).—MAP IV.

177. This small asterism is situated between the feet of Virgo, on the north, and the tail of Hydra, on the south. It has but few stars, and those only of the 5th and 6th magnitudes. It is often omitted altogether from the constellations.

CENTAURUS (THE CENTAUR).—MAP IV. AND VII.

178. This fabulous monster is represented by the figure of a man, terminating in the body of a horse, holding a wolf at arm's

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TELESCOPIC OBJECTS.—Alpha? Beta? Delta? Epsilon? Zeta? Eta? Iota? Xi? What rich group? Point out on the map. What nebulæ?

177. Describe Nocta, its situation, stars, &c.

length in one hand, while he transfixes its body with a spear in the other.

Although this constellation occupies a large space in the southern hemisphere, yet it is so low down that the main part of it cannot be seen in our latitude. It is situated south of Spica Virginis, with a mean declination of 50°. It contains thirty-five stars, including two of the 1st magnitude, one of the 2d, and six of the 3d; the brightest of which are not visible in the United States.

179. *Theta* is a star of between the 2d and 3d magnitude, in the east shoulder, and may be seen from this latitude, during the month of June, being about 27° S. by E. from Spica Virginis, and 12° or 13° above the southern horizon. It is easily recognized in a clear evening, from the circumstance that there is no other star of similar brightness in the same region, for which it can be mistaken. It is so nearly on the same meridian with Arcturus that it culminates but ten minutes before it.

Iota is a star of between the 4th and 5th magnitude, in the west shoulder, 9½° W. of Theta. It is about 26° almost directly south of Spica Virginis, and is on the meridian nearly at the same time.

Mu and *Nu* are stars of the 4th magnitude, in the breast, very near together, and form a regular triangle with the two stars in the shoulders.

A few degrees north of the two stars in the shoulders, are four small stars in the head. The relative position of the stars in the head and shoulders is very similar to that of the stars in the head and shoulders of Orion.

HISTORY.

Centaurs, in mythology, were a kind of fabulous monsters, half men and half horses. This fable is, however, differently interpreted; some suppose the Centaurs to have been a body of shepherds and herdsmen, rich in cattle, who inhabited the mountains of Arcadia, and to whom is attributed the invention of pastoral poetry. But Plutarch and Pliny are of opinion that such monsters have really existed. Others say, that under the reign of Ixion, king of Thessaly, a herd of bulls ran mad, and ravaged the whole country, rendering the mountains inaccessible; and that some young men, who had found the art of taming and mounting horses, undertook to expel these noxious animals, which they pursued on horseback, and thence obtained the appellation of *Centaurs*.

This success rendering them insolent, they insulted the Lapithæ, a people of Thessaly; and because, when attacked, they fled with great rapidity, it was supposed that they were half horses and half men; men on horses being at that period a very uncommon sight, and the two appearing, especially at a distance, to constitute but one animal. So the Spanish cavalry at first seemed to the astonished Mexicans, who imagined the horse and his rider, like the Centaurs of the ancients, to be some monstrous animal of a terrible form.

The Centaurs, in reality, were a tribe of Lapithæ, who resided near Mount Pelion, and first invented the art of breaking horses, as intimated by Virgil.

"The Lapithæ to chariots add the state
Of bits and bridles; taught the steed to bound
To turn the ring, and trace the mazy ground;
To stop, to fly, the rules of war to know;
To obey the rider, and to dare the foe."

Centaurus is so low down in the south that it would be of no service to describe its telescopic objects.

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178. How is Centaurus represented? Its situation? Number of stars, &c.? 179. Theta Iota, Mu, Nu, &c.?

HISTORY.—What was Centaurus? Different opinions?

LUPUS (THE WOLF).—MAPS V. AND VII.

180. This constellation is situated next east of the Centaur, and south of Libra; and is so low down in the southern hemisphere, that only a few stars in the group are visible to us. It contains twenty-four stars, including three of the 3d magnitude, and as many of the 4th; the brightest of which, when on the meridian, may be seen in a clear evening, just above the southern horizon. Their particular situation, however, will be better traced out by reference to the map than by written directions.

The most favorable time for observing this constellation is toward the latter end of June.

HISTORY.

This constellation, according to fable, is Lycaon, king of Arcadia, who lived about 3600 years ago, and was changed into a wolf by Jupiter, because he offered human victims on the altars of the god Pan. Some attribute this metamorphosis to another cause. The sins of mankind, as they relate, had become so enormous, that Jupiter visited the earth to punish its wickedness and impiety. He came to Arcadia, where he was announced as a god, and the people began to pay proper adoration to his divinity. Lycaon, however, who used to sacrifice all strangers to his wanton cruelty, laughed at the pious prayers of his subjects, and to try the divinity of the god, served up human flesh on his table. This impiety so offended Jupiter, that he immediately destroyed the house of Lycaon, and changed him into a wolf.

"Of these he murders one; he boils the flesh,
And lays the mangled morsels in a dish;
Some part he roasts; then serves it up so dress'd,
And bids me welcome to his human feast.
Moved with disdain, the table I o'erturned,
And with avenging flames the palace burn'd.
The tyrant in a fright for shelter gains
The neighboring fields, and scours along the plains:
Howling he fled, and fain he would have spoke,
But human voice his brutal tongue forsook.
His mantle, now his hide, with rugged hairs,
Cleaves to his back: a famish'd face he bears;
His arms descend, his shoulders sink away
To multiply his legs for chase of prey;
He grows a wolf."—*Ovid. Met.* B. i.

TELESCOPIC OBJECTS.

1. α LUPI—A star with a distant companion, in the tail of Lupus; R. A. 5h. 25m. 40s.; Dec. S. 17° 56′ 5″. A 3½, pale yellow; B 9½, grey. To find, draw a line from the central star of Orion's belt, through θ and its nebulous patch on the sword, as low down, and Sirius, and you meet α Lupi.

2. β LUPI—A DOUBLE STAR; R. A. 5h. 21m. 23s.; Dec. S. 20° 53′ 5″. A 4, deep yellow; B 11, blue.

3. γ LUPI—A wide TRIPLE STAR in a barren field; R. A. 5h. 37m. 48s.; Dec. 22° 30′ 2″. A 4, light yellow; B 6½, pale green; C 13, dusky. A line from δ Orionis through the second cluster, and carried 16° beyond, falls upon it.

4. A bright STELLAR NEBULA, of a milky white tinge; R. A. 5h. 17m. 50s. Dec. S. 24° 39′ 9″. A fine object blazing towards the centre.

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180. Situation of Lupus? Number and magnitude of its stars? Best time to observe?
HISTORY.—What was Lupus originally? Why changed and by whom? Described by what poet?
TELESCOPIC OBJECTS.—Alpha? Beta? Gamma? What Nebula?

LIBRA (THE SCALES).—MAP IV. AND V.

181. This is the seventh sign, and eighth constellation, from the vernal equinox, and is situated in the Zodiac, next east of Virgo.

The sun enters this *sign*, at the autumnal equinox, on the 23d of September; but does not reach the *constellation* before the 27th of October. When the sun enters the sign Libra, the days and nights are equal all over the world, and seem to observe a kind of equilibrium, like a balance.

When, however, it is said that the vernal and autumnal equinoxes are in Aries and Libra, and the tropics in Cancer and Capricorn, it must be remembered that the *signs* Aries and Libra, Cancer and Capricorn, and not the constellations of these names, are meant: for the equinoxes are now in the constellations Pisces and Virgo, and the tropics in Gemini and Sagittarius; *each constellation having gone forward one sign in the ecliptic.*

About 22 centuries ago, the *constellation* Libra coincided with the *sign* Libra; but having advanced 30° or more in the ecliptic, it is now in the *sign* Scorpio, and the constellation Scorpio is in the *sign* Sagittarius, and so on.

While Aries is now advanced a whole sign above the equinoctial point into north declination, Libra has descended as far below it into south declination.

182. Libra contains fifty-one stars, including two of the 2d magnitude, two of the 3d, and twelve of the 4th. Its mean declination is 8° south, and its mean right ascension 226°. Its center is therefore on the meridian about the 22d of June.

It may be known by means of its four principal stars, forming a quadrilateral figure, lying northeast and southwest, and having its upper and lower corners nearly in a line running north and south. The two stars which form the N. E. side of the square, are situated about 7° apart, and distinguish the Northern Scale. The two stars which form the S. W. side of the square are situated about 6° apart, and distinguish the Southern Scale.

Zubeneschamali, in the Southern Scale, about 21° E. of Spica, and 8° E. of Lambda Virginis, is a star of the 2d magnitude, and is situated very near the ecliptic, about 42½° E. of the autumnal equinox. The distance from this star down to Theta Centauri is about 23°, with which, and Spica Virginis, it forms a large triangle, on the right.

Zubenelgemabi, the uppermost star in the Northern Scale, is also of the 2d magnitude, 9½° above Zubeneschamali, toward the northeast, and it comes to the meridian about twenty-six minutes after it, on the 23d of June. Zubenelgemabi is the northernmost of the four bright stars in this figure, and is exactly opposite the lower one, which is 11° south of it.

Zubenhakrabi is a star of the 3d magnitude in the Northern Scale, 7° S. E. of Zubenelgemabi, and nearly opposite to Zubeneschamali, at the distance of 11° on the east. These two make the diagonal of the square east and west.

Iota is a star of the 4th magnitude, and constitutes the southernmost corner of the square. It is about 6° S. E. of Zubeneschamali, and 11° S. of Zubenelgemabi, with which it forms the other diagonal north and south.

Zebenelgubi is a star of the 3d magnitude, situated below the Southern Scale, at the

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181. Order and situation of Libra? What circumstance suggesting a balance? What remarks respecting the distinction between the *signs* and the constellations? 182. Number of stars in Libra? Its mean declination? Right ascension? When on the meridian? How may it be known? Describe the four stars. Closing remarks?

distance of 6° from Iota, and marks the southern limit of the Zodiac. It is situated in a right line with, and nearly midway between Spica Virginis and Beta Scorpionis: and comes to the meridian nearly at the same moment with Nekkar, in the head of Bootes.

The remaining stars in this constellation are too small to engage attention.

The scholar, in tracing out this constellation in the heavens, will perceive that Lambda and Mu, which lie in the feet of Virgo on the west, form, with Zubeneschamali and Zubenelgemabi, almost as handsome and perfect a figure, as the other two stars in the Balance do on the east.

HISTORY.

Virgo was the goddess of justice, and Libra, the scales, which she is usually represented as holding in her left hand, are the appropriate emblem of her office.

The Libra of the Zodiac, says Maurice, in his Indian Antiquities, is perpetually seen upon all the hieroglyphics of Egypt; which is at once an argument of the great antiquity of this asterism, and of the probability of its having been originally fabricated by the astronomical sons of Misraim. In some few zodiacs, Astræa, or the virgin who holds the balance in her hand as an emblem of equal justice, is not drawn. Such are the zodiacs of Esne and Dendera. Humboldt is of opinion, that although the Romans introduced this constellation into their zodiac in the reign of Julius Cæsar, still it might have been used by the Egyptians and other nations of very remote antiquity.

It is generally supposed that the figure of the balance has been used by all nations to denote the equality of the days and nights, at the period of the sun's arriving at this sign. It has also been observed, that at this season there is a greater uniformity in the temperature of the air all over the earth's surface.

Others affirm, that the *beam* only of the balance was at first placed among the stars, and that the Egyptians thus honored it as their *Nilometer*, or instrument by which they measured the inundations of the Nile. To this custom of measuring the waters of the Nile, it is thought the prophet alludes, when he describes the Almighty as *measuring the waters in the hollow of his hand.*—Isa. xl. 12.

The ancient husbandmen, according to Virgil, were wont to regard this sign as indicating the proper time for sowing their winter grain:—

> "But when Astræa's balance, hung on high,
> Betwixt the nights and days divides the sky,
> Then yoke your oxen, sow your winter grain,
> Till cold December comes with driving rain."

The Greeks declare that the balance was placed among the stars to perpetuate the memory of Mochus, the inventor of weights and measures.

Those who refer the constellations of the Zodiac to the twelve tribes of Israel ascribe the Balance to Asher.

TELESCOPIC OBJECTS.

1. α LIBRÆ—A wide DOUBLE STAR; R. A. 14h. 42m. 02s.; Dec. S. 15° 22′ 3″. A 3, pale yellow; B 6, light grey. Carry a line from Arcturus to Spica; and from thence a rectangular one about 22° to the eastward.

2. β LIBRÆ—A loose DOUBLE STAR; R. A. 15h. 08m. 24s.; Dec. S. 8° 47′ 4″. A 2½, pale emerald; B 12, light blue.

3. ξ LIBRÆ—A fine TRIPLE STAR, between Libra and the right leg of Ophiuchus, 16° from Antares, towards Serpentis; R. A. 15h. 55m. 35s.; Dec. S. 10° 55′ 6″. A 4½, bright white; B 5, pale yellow; C 7½, grey. Map VIII., Fig. 11.

4. A CLOSE CLUSTER, over the beam of the Scales; R. A. 15h. 10m. 26s.; Dec. N. 2° 41′ 3″. A superb object, with a bright central blaze, and outlines in all directions. Map IX., Fig. 51. Appears nebulous through small instruments.

5. A LARGE COMPRESSED CLUSTER of minute stars; R. A. 15h. 08m. 06s.; Dec. S. 20° 26′ 7″. Faint and pale.

HISTORY.—Who was Virgo, &c.? Remark of Maurice? What general supposition? What other explanations?

TELESCOPIC OBJECTS.—Alpha? Beta? What triple star? Map? Clusters and Map?

SERPENS (THE SERPENT).—PLATE V.

183. There are no less than four kinds of serpents placed among the constellations. The first is the Hydra, which is situated south of the Zodiac, below Cancer, Leo and Virgo; the second is Hydrus, which is situated near the south pole; the third is Draco, which is situated about the north pole; and the fourth is the serpent called Serpens Ophiuchi, and is situated chiefly between Libra and Corona Borealis. A large part of this constellation, however, is so blended with Ophiuchus, the Serpent-Bearer, who grasps it in both hands, that the concluding description of it will be deferred until we come to that constellation.

"The *Serpens Ophiuchi* winds his spire
Immense: fewer by *ten* his figure trace;
One of the second rank; ten shun the sight;
And seven, he who bears the monster hides."

184. Those stars which lie scattered along for about 25°, in a serpentine direction between Libra and the Crown, mark the body and head of the Serpent.

About 10° directly S. of the Crown there are three stars of the 3d magnitude, which, with several smaller ones, distinguish the head.

185. *Unuk*, of the 2d magnitude, is the principal star in this constellation. It is situated in the heart, about 10° below those in the head, and may be known by its being in a line with, and between, two stars of the 3d magnitude—the lower one, marked *Epsilon*, being $2\frac{1}{2}$°, and the upper one, marked *Delta*, about $5\frac{1}{2}$° from it. The direction of this line is N. N. W. and S. S. E Unuk may otherwise be known by means of a small star, just above it, marked *Lambda*.

In that part of the Serpent which lies between Corona Borealis and the Scales, about a dozen stars may be counted, of which five or six are conspicuous.

For the remainder of this constellation, the student is referred to Serpentarius.

"Vast as the starry Serpent, that on high
Tracks the clear ether, and divides the sky,
And southward winding from the Northern Wain.
Shoots to remoter spheres its glittering train."—*Statius.*

HISTORY.

The Hivites, of the Old Testament, were worshipers of the Serpent, and were called *Ophites*. The idolatry of these Ophites was extremely ancient, and was connected with

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183. How many serpents among the constellations? Describe each. Which here referred to? Is it fully described? 184. What stars mark the body and head? 185. Name the principal star. Where situated and how known?

HISTORY.—What said of the Hivites? Tradition respecting Ophiuchus? Supposed Scripture reference?

Sabeism, or the worship of the host of heaven. The heresy of the Ophites, mentioned by Mosheim, in his Ecclesiastical History, originated, perhaps, in the admission into the Christian church of some remnant of the ancient and popular sect of Sabeists, who adored the celestial Serpent.

According to ancient tradition, Ophiuchus is the celebrated physician Æsculapius, son of Apollo, who was instructed in the healing art by Chiron the Centaur; and the serpent, which is here placed in his hands, is understood by some to be an emblem of his sagacity and prudence; while others suppose it was designed to denote his skill in healing the bite of this reptile. Biblical critics imagine that this constellation is alluded to in the following passage of the book of Job:—

"By his spirit He hath garnished the Heavens; his hand hath formed the crooked serpent." Mr. Green supposes, however, that the inspired writer here refers to Draco, because it is a more obvious constellation, being nearer the pole where the constellations were more universally noticed; and moreover, because it is a more ancient constellation than the Serpent, and the hieroglyphic by which the Egyptians usually represented the heavens.

TELESCOPIC OBJECTS.

1. α Serpentis (*Unuk*)—A star with a minute companion on the heart of the Serpent; R. A. 15h. 36m. 23s.; Dec. N. 6° 55′ 9″. A 2½, pale yellow; B 15, fine blue. An extremely delicate object.

2. β Serpentis—A delicate double star in the Serpent's under jaw; R. A. 15h. 38m. 48s.; Dec. N. 15° 55′ 7″. A 3½, and B 10, both pale blue.

3. δ Serpentis—An elegant double star in the bend of the neck; R. A. 15h. 27m. 10s.; Dec. N. 11° 04′ 7″. A 3, bright white; B 5, bluish white. A fine object, about 5° N. W. of Unak.

4. η Serpentis—A star with a minute companion in the Serpent's body, nearly midway between η Ophiuchi and α Aquilæ; R. A. 18h. 13m. 02s.; Dec. S. 2° 56′ 0″. A 4, golden yellow; B 13, pale lilac. A delicate and difficult object.

5. ν Serpentis—A wide double star in the middle of the Serpent, 4° northeast of η; R. A. 17h. 11m. 49s.; Dec. S. 12° 40′ 7″. A 4½, pale sea-green; B 9, lilac, with a third star in the field.

6. A delicate double star; R. A. 15h. 11m. 08s.; Dec. N. 2° 22′ 6″. A 5½, pale yellow B 10½, light grey. Look 9° southwest of α Serpentis, 24° southeast of Arcturus.

CORONA BOREALIS (the northern crown).—MAP V.

186. This beautiful constellation may be easily known by means of its six principal stars, which are so placed as to form a circular figure, very much resembling a wreath or crown. It is situated directly north of the Serpent's head, between Bootes on the west, and Hercules on the east.

This asterism was known to the Hebrews by the name of *Ataroth*, and by this name the stars in Corona Borealis are called, in the East, to this day.

187. *Alphacca*, of the 2d magnitude, is the brightest and middle star in the diadem, and about 11° E. of Mirac, in Bootes. It is very readily distinguished from the others both on account of its position and superior brilliancy. Alphacca, Arcturus, and Seginus, form nearly an isosceles triangle, the vertex of which is at Arcturus.

Telescopic Objects.—Alpha? Beta? Delta? Eta? Nu? &c.

186. How may Corona Borealis be known? Where situated? Its Hebrew name?
187. Describe Alphacca? How distinguished? What triangle?

188. This constellation contains twenty-one stars, of which only six or eight are conspicuous; and most of these are not larger than the 3d magnitude. Its mean declination is 30° north, and its mean right ascension 235°; its center is therefore on the meridian about the last of June, and the first of July.

"And, near to *Helice*, effulgent rays
Beam, *Ariadne*, from thy starry crown:
Twenty and *one* her stars; but eight alone
Conspicuous; *one* doubtful, or to claim
The second order, or accept the third."

HISTORY.

This beautiful little cluster of stars is said to be in commemoration of a crown presented by Bacchus to Ariadne, the daughter of Minos, second king of Crete. Theseus, king of Athens (1235 B. C.), was shut up in the celebrated labyrinth of Crete, to be devoured by the ferocious Minotaur which was confined in that place, and which usually fed upon the chosen young men and maidens exacted from the Athenians as a yearly tribute to the tyranny of Minos; but Theseus slew the monster, and being furnished with a clew of thread by Ariadne, who was passionately enamored of him, he extricated himself from the difficult windings of his confinement.

He afterward married the beautiful Ariadne according to promise, and carried her away; but when he arrived at the island of Naxos, he deserted her, notwithstanding he had received from her the most honorable evidence of attachment and endearing tenderness. Ariadne was so disconsolate upon being abandoned by Theseus, that, as some say, she hanged herself; but Plutarch says that she lived many years after, and was espoused to Bacchus, who loved her with much tenderness, and gave her a crown of seven stars which, after her death, was placed among the stars.

"Resolves, for this the dear engaging dame
Should shine forever in the rolls of fame;
And bids her crown among the stars be placed,
And with an eternal constellation graced.
The golden circlet mounts; and, as it flies,
Its diamonds twinkle in the distant skies;
There, in their pristine form, the gemmy rays
Between Alcides and the Dragon blaze."

Manilius, in the first book of his *Astronomicon*, thus speaks of the Crown.

"Near to Bootes the bright crown is view'd,
And shines with stars of different magnitude:
Or placed in front above the rest displays
A vigorous light, and darts surprising rays.
This shone, since Theseus first his faith betray'd,
The monument of the forsaken maid."

TELESCOPIC OBJECTS.

1. α CORONÆ BOREALIS (*Alphacca*)—A bright star with a distant companion; R. A. 15h. 27m. 54s.; Dec. N. 27° 15′ 2″. A 2, brilliant white; B 8, pale violet.

2. γ CORONÆ BOREALIS—A most difficult BINARY STAR, 2½° from Alphacca; R. A. 15h. 36m. 01s.; Dec. N. 26° 48′ 4″; with a distant companion. A 6, flushed white; B, uncertain; C 10, pale lilac.

3. ζ CORONÆ BOREALIS—A fine DOUBLE STAR, 10° north and a little easterly from Alphacca; R. A. 15h. 33m. 21s.; Dec. N. 37° 09′ 6″. A 5, bluish white; B 6, smalt blue. A beautiful object.

4. η CORONÆ BOREALIS—A BINARY STAR, midway between the Northern Crown and the club of Bootes; R. A. 15h. 16m. 36s.; Dec. N. 30° 52′ 2″. A north-northwest ray from α Coronæ, through β, and half as far again, will hit it. A 6, white; B 6½, golden yellow.

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188. How many stars in this constellation? Their magnitudes? Mean declination and right ascension?
HISTORY.—Story respecting Theseus and Ariadne?
TELESCOPIC OBJECTS.—Alpha? Gamma? Zeta? Eta?

Sir John Herschel considered this the most remarkable binary star known, and the only one that had completed a whole revolution since its discovery. Estimated period 432 years.

URSA MINOR (THE LESSER BEAR).—MAP VI.

189. This constellation, though not remarkable in its appear ance, and containing but few conspicuous stars, is, nevertheless, justly distinguished from all others for the peculiar advantage which its position in the heavens is well known to afford to nautical astronomy, and especially to navigation and surveying.

The stars in this group being situated near the celestial pole, appear to revolve about it, very slowly, and in circles so small as never to descend below the horizon. Hence Ursa Minor will be above or below, to the right or left of the pole star, according to the hour; as he makes the entire circuit from east to west every 24 hours.

190. In all ages of the world, this constellation has been more universally observed, and more carefully noticed than any other, on account of the importance which mankind early attached to the position of its principal star. This star, which is so near the true pole of the heavens, has from time immemorial been denominated the NORTH POLAR STAR. By the Greeks it is called *Cynosyre*; by the Romans, *Cynosura*, and by other nations, *Alruccabah*. In most modern treatises it bears the name of *Polaris*, or *Alpha Polaris*.

191 *Polaris* is of the 3d magnitude, or between the 2d and 3d, and situated a little more than a degree and a half from the true pole of the heavens, on that side of it which is toward Cassiopeia and opposite to Ursa Major. Its position is pointed out by the direction of the two *Pointers*, Merak and Dubhe, which lie in the square of Ursa Major. A line joining Beta Cassiopeiæ, which lies at the distance of 32° on one side, and Megrez, which lies at the same distance on the other, will pass through the polar star.

Of the Pole Star Capt. Smyth observes: At present it is only 1° 33′ from the polar point, and by its northerly precession in declination will gradually approach to within 26′ 30″ of it. This proximity to the actual pole will occur in A. D. 2095, but will not recur for 12,860 years. The period of the revolution of the celestial equinoctial pole about the pole of the ecliptic, is nearly 26,000 years; the north celestial pole, therefore, will be about 13,000 years; hence, nearly 49° from the present polar star.

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189. For what is Ursa Minor distinguished? What said of its situation and change of position? 190. What said of the notice taken of it? Position of its principal star? Its Greek and Latin names, &c.? 191. Describe Polaris? How found? Remarks of Capt. Smyth respecting?

192. So general is the popular notion, that the North Polar Star is the true pole of the world, that even surveyors and navigators, who have acquired considerable dexterity in the use of the compass and the quadrant, are not aware that it ever had any deviation, and consequently never make allowance for any. All calculations derived from the observed position of this star, which are founded upon the idea that its bearing is always due north of any place, are necessarily erroneous, since it is in this position only twice in twenty-four hours ; once when above, and once when below the pole.

193. Hence, it is evident that the surveyor who regulates his compass by the North Polar Star, must take his observation when the star is on the meridian, either above or below the pole, or make allowance for its altered position in every other situation. For the same reason must the navigator, who applies his quadrant to this star for the purpose of determining the latitude he is in, make a similar allowance, according as its altitude is greater or less than the true pole of the heavens ; for we have seen that it is alternately half the time *above* and half the time *below* the pole.

194. The method of finding the latitude of a place from the altitude of the polar star, as it is very simple, is very often resorted to. Indeed, in northern latitudes, the situation of this star is more favorable for this purpose than that of any other of the heavenly bodies, because a single observation, taken at any hour of the night with a good instrument, will give the true latitude, without any calculation or correction, except that of its polar aberration.

If the polar star always occupied that point in the heavens which is directly opposite the north pole of the earth, it would be easy to understand how latitude could be determined from it in the northern hemisphere; for in this case, to a person on the equator, the poles of the world would be seen in the horizon. Consequently, the star would appear just visible in the northern horizon, without any elevation. Should the person now travel one degree toward the north, he would see one degree below the star, and he would think it had risen one degree.

And since we always see the whole of the upper hemisphere at one view, when there is nothing in the horizon to obstruct our vision, it follows that if we should travel 10° north of the equator, we should see just 10° below the pole, which would then appear to have risen 10°; and should we stop in the 42d degree of north latitude we should, in like manner, have our horizon just 42° below the pole, or the pole would appear to have an elevation of 42°. Whence we derive this general truth: *The elevation of the pole of the equator is always equal to the latitude of the place of observation.*

Any instrument, then, which will give us the altitude of the north pole, will give us also the latitude of the place.

The method of illustrating this phenomenon, is given in most treatises on the globe,

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192. What popular error? 193. When is the pole star a safe guide for the surveyor or mariner? What allowances should be made by each? 194. What said of finding the latitude by observations upon the pole star? What general rule stated? What error committed ?

and as adopted by teachers generally, is to tell the scholar that the north pole rises higher and higher, as he travels farther and farther toward it. In other words, whatever number of degrees he advances *toward* the north pole, so many degrees will it rise above his horizon. This is not only an obvious *error* in principle, but it misleads the apprehension of the pupil. It is *not* that the *pole is elevated*, but that our *horizon is depressed* as we advance toward the north. The same objection lies against the artificial globe; for it ought to be so fixed that the *horizon* might be raised or depressed, and the pole remain in its own invariable position.

195. Ursa Minor contains twenty-four stars, including three of the 3d magnitude and four of the 4th. The seven principal stars are so situated as to form a figure very much resembling that in the Great Bear, only that the *Dipper* is reversed, and about one half as large as the one in that constellation.

196. The first star in the handle, called *Polaris*, is the polar star, around which the rest constantly revolve. The two last in the bowl of the Dipper, corresponding to the *Pointers* in the Great Bear, are of the 3d magnitude, and situated about 15° from the pole. The brightest of them is called Kochab, which signifies an axle or hinge, probably in reference to its moving so near the axis of the earth.

Kochab may be easily known by its being the brightest and middle one of the three conspicuous stars forming a row, one of which is about 2°, and the other 3° from Kochab. The two brighest of these are situated in the breast and shoulder of the animal, about 3° apart, and are called the *Guards* or *Pointers* of Ursa Minor. They are on the meridian about the 20th of June, but may be seen at all hours of the night, when the sky is clear.

197. Of the four stars which form the bowl of the Dipper, one is so small as hardly to be seen. They lie in a direction toward Gamma in Cepheus; but as they are continually changing their position in the heavens, they may be much better traced out from the map, than from description.

Kochab is about 25° distant from Benetnasch, and about 24° from Dubhe, and hence forms with them a very nearly equilateral triangle.

————"The Lesser Bear
Leads from the pole the lucid band: the stars
Which form this constellation, faintly shine,
Twice twelve in number; only one beams forth
Conspicuous in high splendor, named by Greece
The *Cynosure;* by us, the POLAR STAR."

HISTORY.

The prevailing opinion is that Ursa Major and Ursa Minor are the nymph Calisto and her son Arcas, and that they were transformed into bears by the enraged and imperious Juno, and afterward translated to heaven by the favor of Jupiter, lest they might be destroyed by the huntsmen.

The Chinese claim that the emperor Hong-ti, the grandson of Noah, first discovered

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195. Number of stars in Ursa Minor? Their magnitudes? How situated? 196. Describe Polaris, Kochab, and the Guards or Pointers? 197. Are all the stars distinctly visible? Direction? What triangle?

HISTORY.—What prevailing opinion, or myth? Chinese claim? Phenicians? Greeks?

the polar star, and applied it to purposes of navigation. It is certain that it was used for this purpose in a very remote period of antiquity. From various passages in the ancients, it is manifest that the Phenicians steered by Cynosura, or the Lesser Bear; whereas, the mariners of Greece, and some other nations, steered by the Greater Bear, called Helice, or Helix.

Lucan, a Latin poet, who flourished about the time of the birth of our Saviour, thus adverts to the practice of steering vessels by Cynosura:—

"Unstable Tyre now knit to firmer ground,
With Sidon for her purple shells renown'd,
Safe in the *Cynosure* their glittering guide
With well-directed navies stem the tide."
ROWE'S Translation, B. iii.

The following extracts from other poets contain allusions to the same fact:

"Phenicia, spurning Asia's bounding strand,
By the bright *Pole star's* steady radiance led,
Bade to the winds her daring sails expand,
And fearless plough'd old Ocean's stormy bed."
MAURICE'S *Elegy on Sir W. Jones.*

"Ye radiant signs, who, from the ethereal plain
Sidonians guide, and *Greeks* upon the main,
Who from your poles all earthly things explore,
And never set beneath the western shore."
OVID'S *Tristia.*

"Of all yon multitude of golden stars,
Which the wide rounding sphere incessant bears.
The cautious mariner relies on none,
But keeps him to the constant pole alone."
LUCAN'S Pharsalia, B. viii. v. 225.

Ursa Major and Ursa Minor are sometimes called *Triones*, and sometimes the Greater and Lesser Wains. In Pennington's Memoirs of the learned Mrs. Carter, we have the following beautiful lines:—

"Here Cassiopeia fills a lucid throne,
There, blaze the splendors of the Northern Crown;
While the slow *Car*, the cold *Triones* roll
O'er the pale countries of the frozen pole:
Whose faithful beams conduct the wandering ship
Through the wide desert of the pathless deep."

Thales, an eminent geometrician and astronomer, and one of the seven wise men of Greece, who flourished six hundred years before the Christian era, is generally reputed to be the inventor of this constellation, and to have taught the use of it to the Phenician navigators; it is certain that he brought the knowledge of it with him from Phenice into Greece, with many other discoveries both in astronomy and mathematics.

Until the properties of the magnet were known and applied to the use of navigation, and for a long time after, the north polar star was the only sure guide. At what time the attractive powers of the magnet were first known, is not certain; they were known in Europe about six hundred years before the Christian era; and by the Chinese records, it is said that its polar attraction was known in that country at least one thousand years earlier.

TELESCOPIC OBJECTS.

1. α URSÆ MINORIS (*Polaris*)—A DOUBLE STAR; R. A. 1h. 2m. 10s.; Dec. N. 88° 27′ 4″. A 2½, topaz yellow; B 9½, pale white. Map VIII., Fig. 12.

2. β URSÆ MINORIS (*Kochab*)—A star with a distant companion in the left shoulder; R. A. 14h. 51m. 14s.; Dec. N. 74° 48′ 2″. A 3, reddish; B 11, pale grey—several small stars in the field.

3. δ URSÆ MINORIS—A star with a very distant telescopic companion in the middle of the tail of the figure; R. A. 18h. 23m. 56s.; Dec. N. 86° 35′ 4″. A 3, greenish tinge; B 12, grey.

What proofs from the poets? What other names for Ursa Major and Ursa Minor? What said of Thales? Use of the pole star? The magnet?

TELESCOPIC OBJECTS.—Alpha? Show on the map, Beta—Delta—Epsilon—Zeta.

4. ε Ursæ Minoris—A star with a minute companion, at the root of the tail; R. A. 17h. 02m. 37s.; Dec. N. 82° 17′ 01″. A 4, bright yellow; B 12, pale blue; three other telescopic stars in the field. It is easily found, being the third star from Polaris.

5. ζ Ursæ Minoris—A double star in the middle of the body; R. A. 15h. 49m. 52s.; Dec. N. 78° 16′ 07″. A 4, flushed white; B 11, bluish with a yellow star of the 9th magnitude in the field.

CHAPTER IX.

CONSTELLATIONS ON THE MERIDIAN IN JULY.

SCORPIO (the scorpion).—MAP V.

198. This is the eighth sign, and ninth constellation, in the order of the Zodiac. It presents one of the most interesting groups of stars for the pupil to trace out that is to be found in the southern hemisphere. It is situated southward and eastward of Libra, and is on the meridian the 10th of July.

The sun enters this *sign* on the 23d of October, but does not reach the *constellation* before the 20th of November. When astronomy was first cultivated in the East, the two solstices and the two equinoxes took place when the sun was in Aquarius and Leo, Taurus and Scorpio, respectively.

199. Scorpio contains, according to Flamsted, forty-four stars, including one of the 1st magnitude, one of the 2d, and eleven of the 3d. It is readily distinguished from all others by the peculiar luster and the position of its principal stars.

Antares is the principal star, and is situated in the heart of the Scorpion, about 19° east of Zubenelgubi, the southernmost star in the Balance. Antares is the most brilliant star in that region of the skies, and may be otherwise distinguished by its remarkably red appearance. Its declination is about 26° S. It comes to the meridian about three hours after Spica Virginis, or fifty minutes after Corona Borealis, on the 10th of July. It is one of the stars from which the moon's distance is reckoned for computing the longitude at sea.

There are four great stars in the heavens, *Fomalhaut*, *Aldebaran*, *Regulus*, and *Antares*, which formerly answered to the solstitial and equinoctial points, and which were much noticed by the astronomers of the East.

200. About 8½° northwest of Antares, is a star of the 2d

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198. Order of Scorpio among the signs, &c.? Its comparative interest? Situation? When does the sun enter this *sign?* When the *constellation?* How with the solstices and equinoxes anciently? Why not so now? 199. Number and magnitudes of the stars in Scorpio? How distinguished? Name and position of its principal star? How known? What use made of it? What three other stars mentioned? 200. What other

magnitude, in the head of the Scorpion, called *Graffias.* It is but one degree north of the earth's orbit. It may be recognized by means of a small star, situated about a degree northeast of it, and also by its forming a slight curve with two other stars of the 3d magnitude, situated below it, each about 3° apart. The broad part of the constellation near Graffias, is powdered with numerous small stars, converging down to a point at Antares, and resembling in figure a boy's kite.

201. As you proceed from Antares, there are ten conspicuous stars, chiefly of the 3d magnitude, which mark the tail of the kite, extending down, first in a south-southeasterly direction about 17°, thence easterly about 8° further, when they turn, and advance about 8° toward the north, forming a curve like a shepherd's crook, or the bottom part of the letter S. This crooked line of stars, forming the tail of the Scorpion, is very conspicuous, and may be easily traced.

The first star below Antares, which is the last in the back, is of only the 4th magnitude. It is about 2° southeast of Antares, and is denoted by the Greek name of T.

Epsilon, of the 3d magnitude, is the second star from Antares, and the first in the tail It is situated about 7° below the star T, but inclining a little to the east.

Mu, of the 3d magnitude, is the 3d star from Antares. It is situated 4⅓° below Epsilon. It may otherwise be known by means of a small star close by it, on the left.

Zeta, of about the same magnitude, and situated about as far below Mu, is the fourth star from Antares. Here the line turns suddenly to the east.

Eta, also of the 3d magnitude, is the fifth star from Antares, and about 3½° east of Zeta.

Theta, of the same magnitude, is the sixth star from Antares, and about 4½° east of Eta. Here, the line turns again, curving to the north, and terminates in a couple of stars.

Iota is the seventh star from Antares, 3½° above Theta, curving a little to the left. It is a star of the 3d magnitude, and may be known by means of a small star, almost touching it, on the east.

Kappa, a star of equal brightness, is less than 2° above Iota, and a little to the right.

Lesuth, of the 3d magnitude, is the brightest of the two last, in the tail, and is situated about 3° above Kappa, still further to the right. It may readily be known by means of a smaller star, close by it, on the west.

202. This is a very beautiful group of stars, and easily traced out in the heavens. It furnishes striking evidence of the facility with which most of the constellations may be so accurately delineated, as to preclude everything like uncertainty in the knowledge of their relative situation.

> "The heart with luster of amazing force,
> Refulgent vibrates; faint the other parts,
> And ill-defined by stars of meaner note."

HISTORY.

This sign was anciently represented by various symbols, sometimes by a snake, and sometimes by a crocodile; but most commonly by the scorpion. This last symbol is

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star described? Size and position? How recognized? What said of the broad part or body of Scorpio? 201. What stars form the tail of Scorpio? Are they conspicuous? Name and describe in detail? 202. General remarks respecting this constellation?

HISTORY.—How was Scorpio anciently delineated? How regarded by ancient astrolofound on the Mithraic monuments, which is pretty good evidence that these monuments were constructed when the vernal equinox accorded with Taurus.

On both the zodiacs of Dendera, there are rude delineations of this animal; that on the portico differs considerably from that on the other zodiac, now in the Louvre.

Scorpio was considered by the ancient astrologers as a sign accursed. The Egyptians fixed the entrance of the sun into Scorpio as the commencement of the reign of Typhon, when the Greeks fabled the death of Orion. When the sun was in Scorpio, in the month of *Athyr*, as Plutarch informs us, the Egyptians inclosed the body of their god Osiris in an *ark*, or chest, and during this ceremony a great annual festival was celebrated. Three days after the priests had inclosed Osiris in the ark, they pretended to have found him again. The death of Osiris, then, was lamented when the sun in *Scorpio* descended to the lower hemisphere, and when he arose at the vernal equinox, then Osiris was said to be born anew.

The Egyptians or Chaldeans, who first arranged the Zodiac, might have placed Scorpio in this part of the heavens to denote that when the sun enters this sign, the diseases incident to the fruit season would prevail; since Autumn, which abounded in fruit, often brought with it a great variety of diseases, and might be thus fitly represented by that venomous animal, the scorpion, who, as he recedes, wounds with a sting in his tail.

Mars was the tutelary deity of the Scorpion, and to this circumstance is owing all that jargon of the astrologers, who say that there is a great analogy between the malign influence of the planet Mars and this sign. To this also is owing the doctrine of the alchemists, that iron, which metal they call Mars, is under the dominion of Scorpio; so that the transmutation of it into gold can be effected only when the sun is in this sign.

The constellation of the Scorpion is very ancient. Ovid thus mentions it in his beautiful fable of Phaeton:—

> "There is a place above, where Scorpio bent,
> In tail and arms surrounds a vast extent;
> In a wide circuit of the heavens he shines,
> And fills the place of two celestial signs."

According to Ovid, this is the famous scorpion which sprang out of the earth at the command of Juno, and stung Orion; of which wound he died. It was in this way the imperious goddess chose to punish the vanity of the hero and the hunter, for boasting that there was not on earth any animal which he could not conquer.

> "Words that provoked the gods once from him fell,
> 'No beasts so fierce,' said he, 'but I can quell;'
> When lo! the earth a baleful scorpion sent,
> To kill Latona was the dire intent;
> Orion saved her, though himself was slain,
> But did for that a spacious place obtain
> In heaven: '*to thee my life*,' said she, '*was dear*,
> And *for thy merit shine illustrious there*."

Although both Orion and Scorpio were honored by the celestials with a place among the stars, yet their situations were so ordered that when one rose the other should set, and *vice versa;* so that they never appear in the same hemisphere at the same time.

In the Hebrew zodiac this sign is allotted to Dan, because it is written, "Dan shall be a serpent by the way, an adder in the path."

TELESCOPIC OBJECTS.

1. α Scorpii (*Antares*)—A bright star with a companion in the heart of Scorpio; R. A 16h. 19m. 36s.; Dec. S. 26° 04′ 3″. A 1, fiery red; B 8, pale. Very close.

2. β Scorpii (*Graffias*)—A star with a companion in the head; R. A. 15h. 56m. 08s.; Dec. S. 19° 21′ 7″. A 2, pale white; B 5½, lilac tinge.

3. ν Scorpii—A neat double star, east by north from β about 2°; R. A. 16h. 02m. 42s.; Dec. S. 19° 02′ 3″. A 4, bright white; B 7, pale lilac. Professor Mitchell registers this as a triple star.

4. σ Scorpii—A delicate double star in the body of the figure; R. A. 16h. 11m. 28s.;

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gers? Egyptian myth respecting Typhon, &c.? Supposed reason why Scorpio was placed where it is? Why do astrologers connect Mars with Scorpio? The Alchemists? What poetic proof of the antiquity of Scorpio? Ovid's myth respecting? Relative position of Orion and Scorpio? Place of Scorpio in the Hebrew Zodiac, and why?

Telescopic Objects.—Alpha? Beta? Nu? Sigma? What cluster? Point out on the map. What Nebula?

Dec. S. 26° 12′ 2″. About 2° west by north of Antares. A 4, creamy white; B 9½ lilac tint.

5. A COMPRESSED GLOBULAR CLUSTER in the right foot of Ophiuchus, or the Scorpion's back; R. A. 16h. 07m. 28s.; Dec. S. 22° 35′ 4″. Half way between α and β Scorpii, or 4° east of δ. A fine bright object, in an open space, with a few telescopic stars in the field. Pronounced by Herschel "the richest and most condensed mass of stars which the firmament can offer to the contemplation of astronomers." Map IX., Fig. 52.

6. A compressed mass of very small stars, in the middle of the body, with outlayers, and a few stellar companions in the field; R. A. 16h. 13m. 51s.; Dec. S. 26° 07′ 5″. It is 1½° west of Antares. Elongated and bright in the center.

7. A fine large RESOLVABLE NEBULA at the root of the tail, about 7° southeast from Antares; R. A. 16h. 51m. 04s.; Dec. S. 29° 50′ 6″. A mass of small stars running up to a blaze in the center—has been mistaken for a comet.

HERCULES.—MAP V.

203. Hercules is represented on the map invested with the skin of the Nemæan Lion, holding a massy club in his right hand, and the three-headed dog Cerberus in his left. He occupies a large space in the northern hemisphere, with one foot resting on the head of Draco, on the north, and his head nearly touching that of Ophiuchus, on the south. This constellation extends from 12° to 50° north declination, and its mean right ascension is 255°; consequently its centre is on the meridian about the 21st of July.

204. Hercules is bounded by Draco on the north, Lyra on the east, Ophiuchus or the Serpent-Bearer on the south, and the Serpent and the Crown on the west. It contains one hundred and thirteen stars, including one of the 2d, or of between the 2d and 3d magnitudes, nine of the 3d magnitude, and nineteen of the 4th. The principal star is *Ras Algethi*, and is situated in the head, about 25° southeast of Corona Borealis. It may be readily known by means of another bright star of equal magnitude, 5° east-southeast of it, called Ras Alhague. Ras Alhague marks the head of Ophiuchus, and Ras Algethi that of Hercules. These two stars are always seen together like the bright pairs in Aries, Gemini, the Little Dog, &c. They come to our meridian about the 28th of July, near where the sun does the last of April, or the middle of August.

About midway between Ras Algethi on the southeast, and Ariadne's Crown on the northwest, may be seen Beta and Gamma, two stars of the 3d magnitude, situated in the west shoulder, about 3° apart. The northernmost of these two is called *Rutilicus*.

Those four stars in the shape of a diamond, 8° or 10° southwest of the two in the shoulder of Hercules, are situated in the head of the Serpent.

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203. Describe Hercules? His magnitude and position? When on the meridian? 204. How bounded? Number of stars? Their size? Principal star, and how known? What said of Ras Alhague, and Ras Algethi? Of Beta and Gamma?

205. About 12° E. N. E. of Rutilicus, and $10\frac{1}{2}$° directly north o Ras Algethi, are two stars of the 4th magnitude, in the east shoulder. They may be known by two very minute stars a little above them on the left. The two stars in each shoulder of Hercules, with Ras Algethi in the head, form a regular triangle.

The left, or east arm of Hercules, which grasps the triple-headed monster Cerberus, may be traced by means of three or four stars of the 4th magnitude, situated in a row, 3° and 4° apart, extending from the shoulder, in a northeasterly direction. That small cluster, situated in a triangular form, about 14° northeast of Ras Algethi, and 13° east-southeast of the left shoulder, distinguish the head of Cerberus.

Eighteen or 20° northeast of the Crown, are four stars of the 3d and 4th magnitudes, forming an irregular square, of which the two southern ones are about 4° apart, and in a line 6° or 7° south of the two northern ones, which are nearly 7° apart.

Pi, in the northeast corner, may be known by means of one or two other small stars, close by it, on the east. *Eta*, in the northwest corner, may be known by its being in a row with two smaller stars, extending toward the northwest, and about 4° apart. The stars of the 4th magnitude, just south of the Dragon's head, point out the left foot and ankle of Hercules.

Several other stars, of the 3d and 4th magnitudes, may be traced out in this constellation, by reference to the map.

HISTORY.

This constellation is intended to immortalize the name of Hercules, the Theban, so celebrated in antiquity for his heroic valor and invincible prowess. According to the ancients, there were many persons of this name. Of all these, the son of Jupiter and Alcmena is the most celebrated, and to him the actions of the others have been generally attributed.

The birth of Hercules was attended with many miraculous events. He was brought up at Tirynthus, or at Thebes, and before he had completed his eighth month, the jealousy of Juno, who was intent upon his destruction, sent two snakes to devour him. Not terrified at the sight of the serpents, he boldly seized them, and squeezed them to death, while his brother Iphicles alarmed the house with his frightful shrieks.

He was early instructed in the liberal arts, and soon became the pupil of the centaur Chiron, under whom he rendered himself the most valiant and accomplished of all the heroes of antiquity. In the 18th year of his age, he commenced his arduous and glorious pursuits. He subdued a lion that devoured the flocks of his supposed father, Amphitryon. After he had destroyed the lion, he delivered his country from the annual tribute of a hundred oxen, which it paid to Erginus.

As Hercules, by the will of Jupiter, was subjected to the power of Eurystheus, and obliged to obey him in every respect, Eurystheus, jealous of his rising fame and power, ordered him to appear at Mycenæ, and perform the labors which, by priority of birth, he was empowered to impose upon him. Hercules refused, but afterwards consulted the oracle of Apollo, and was told that he must be subservient, for twelve years, to the will of Eurystheus, in compliance with the commands of Jupiter; and that, after he had achieved the most celebrated labors, he should be reckoned in the number of the gods. So plain an answer determined him to go to Mycenæ, and to bear with fortitude whatever gods or men should impose upon him. Eurystheus, seeing so great a man totally subjected to him, and apprehensive of so powerful an enemy, commanded him to achieve a number of enterprises the most difficult and arduous ever known, generally called the TWELVE LABORS OF HERCULES. Being furnished with complete armor by the favor of the gods, he boldly encountered the imposed labors.

1. He subdued the Nemæan Lion in his den, and invested himself with his skin.
2. He destroyed the Lernæan Hydra, with a hundred hissing heads, and dipped his arrows in the gall of the monster, to render their wounds incurable.
3. He took alive the stag with golden horns and brazen feet, so famous for its incredible swiftness, after pursuing it for twelve months, and presented it, unhurt, to Eurystheus.
4. He took alive, the Erymanthian Boar, and killed the Centaurs who opposed him.

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205. What two other stars, and what triangle? How trace the left or east arm of Hercules? What four stars, and forming what? Describe Pi, and how known. Eta? Any other stars?

HISTORY.—Design of this constellation? Story of the birth of Hercules? His wonderful

5. He cleansed the stables of Augias, in which 3,000 oxen had been confined for many years.
6. He killed the carnivorous birds which ravaged the country of Arcadia, and fed on human flesh.
7. He took alive, and brought into Peloponnesus, the wild bull of Crete, which no mortal durst look upon.
8. He obtained for Eurystheus the mares of Diomedes, which fed on human flesh after having given their owner to be first eaten by them.
9. He obtained the girdle of the queen of the Amazons, a formidable nation of warlike females.
10. He killed the monster Geryon, king of Gades, and brought away his numerous flocks, which fed upon human flesh.
11. He obtained the golden apples from the garden of the Hesperides, which were watched by a dragon.
12. And finally, he brought up to the earth the three-headed dog Cerberus, the guardian of the entrance to the infernal regions.

According to Dupuis, the twelve labors of Hercules are only a figurative representation of the annual course of the *sun* through the twelve signs of the Zodiac; Hercules being put for the sun, inasmuch as it is the powerful planet which animates and imparts fecundity to the universe, and whose divinity has been honored, in every quarter, by temples and altars, and consecrated in the religious strains of all nations.

Thus Virgil, in the eighth book of his Æneid, records the deeds of Hercules, and celebrates his praise:—

"The lay records the labors, and the praise,
And all the immortal acts of Hercules.
First, how the mighty babe, when swath'd in bands,
The serpents strangled with his infant hands;
Then, as in years and matchless force he grew,
The Œchalian walls and Trojan overthrew,
Besides a thousand hazards they relate,
Procured by Juno's and Eurystheus' hate.
Thy hands, unconquer'd hero, could subdue
The cloud-born Centaur, and the monster crew:
Nor thy resistless arm the bull withstood;
Nor he, the roaring terror of the wood.
The triple porter of the Stygian seat
With lolling tongue lay fawning at thy feet,
And, seized with fear, forgot the mangled meat.
The infernal waters trembled at thy sight:
Thee, god, no face of danger could affright;
Nor huge Typhæus, nor the unnumber'd snake,
Increased with hissing heads, in Lerna's lake."

Besides these arduous labors which the jealousy of Eurystheus imposed upon him, he also achieved others of his own accord, equally celebrated. Before he delivered himself up to the king of Mycenæ he accompanied the Argonauts to Colchis. He assisted the gods in their wars against the giants, and it was through him alone that Jupiter obtained the victory. He conquered Laomedon and pillaged Troy.

At three different times he experienced fits of insanity. In the second, he slew the brother of his beloved Iole; in the third he attempted to carry away the sacred tripod from Apollo's temple at Delphi, for which the oracle told him he must be sold as a slave. He was sold accordingly to Omphale, queen of Lydia, who restored him to liberty, and married him. After this he returned to Peloponnesus, and re-established on the throne of Sparta his friend Tyndarus, who had been expelled by Hippocoon. He became enamored of Dejanira, whom, after having overcome all his rivals, he married; but was obliged to leave his father-in-law's kingdom, because he had inadvertently killed a man with a blow of his fist. He retired to the court of Ceyx, king of Trachina, and in his way was stopped by the streams of the Evenus, where he slew the Centaur Nessus, for presuming to offer indignity to his beloved Dejanira. The Centaur, on expiring, gave to Dejanira the celebrated tunic which afterward caused the death of Hercules. "This tunic," said the expiring monster, "has the virtue to recall a husband from unlawful love." Dejanira, fearing lest Hercules should relapse again into love for the beautiful Iole, gave him the fatal tunic, which was so infected with the poison of the Lernæan

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exploits? Origin and character of the twelve labors? What are these labors supposed to represent? What quotation from Virgil? Story of the death of Hercules? Ovid?

Hydra, that he had no sooner invested himself with it, than it began to penetrate his bones, and to boil through all his veins. He attempted to pull it off, but it was too late.

> "As the red iron hisses in the flood,
> So boils the venom in his curdling blood.
> Now with the greedy flame his entrails glow,
> And livid sweats down all his body flow;
> The crackling nerves, burnt up, are burst in twain,
> The lurking venom melts his swimming brain."

As the distemper was incurable, he implored the protection of Jupiter, gave his bow and arrows to Philoctetes, and erected a large burning pile on the top of Mount Œta. He spread on the pile the skin of the Nemæan lion, and laid himself down upon it, as on a bed, leaning his head upon his club. Philoctetes set fire to the pile, and the hero saw himself, on a sudden, surrounded by the most appalling flames; yet he did not betray any marks of fear or astonishment. Jupiter saw him from heaven, and told the surrounding gods, who would have drenched the pile with tears, while they entreated that he would raise to the skies the immortal part of a hero who had cleared the earth from so many monsters and tyrants; and thus the thunderer spake:—

> ———"Be all your fears forborne:
> The Œtean fires do thou, great hero, scorn.
> Who vanquish'd all things shall subdue the flame
> That part alone of gross maternal frame
> Fire shall devour; while what from me he drew
> Shall live immortal, and its force subdue:
> *That*, when he's dead, I'll raise to realms above;—
> May all the powers the righteous act approve."
> *Ovid's Met.* lib. ix.

Accordingly, after the mortal part of Hercules was consumed, as the ancient poets say, he was carried up to heaven in a chariot drawn by four horses.

> "Quem pater omnipotens inter cava nubila raptum,
> Quadrijugo curru radiantibus intulit astris."

> ———"Almighty Jove
> In his swift car his honor'd offspring drove;
> High o'er the hollow clouds the coursers fly,
> And lodge the hero in the starry sky."
> *Ovid's Met.* lib. ix. v. 271.

TELESCOPIC OBJECTS.

1. α Herculis (*Ras Algethi*)—A beautiful double star in the head of Hercules; R. A. 17h. 07m. 21s.; Dec. N. 14° 34′ 05″. A 3½, orange; B 5½, greenish. Map VIII., Fig. 13.

2. β Herculis (*Rutilicus*)—A fine double star in a barren field, on the hero's left shoulder; R. A. 16h. 23m. 21s.; Dec. N. 21° 50′ 6″. A 2½, pale yellow; B 11, lilac tint.

3. γ Herculis—An open double star in a dark field, on the left arm; R. A. 16h. 14m. 53s.; Dec. N. 19° 32′ 0″. A 3½, silvery white; B 10, lilac. About half-way from *Ras Algethi*, in the head, to *Alphacca* in the Northern Crown.

4. δ Herculis—A binary star on the right shoulder, and about 11° due north of α; R. A. 17h. 08m. 28s.; Dec. N. 25° 01′ 9″. A 4, greenish white; B 8½, grape red. It forms an equilateral triangle with α and β.

5. ζ Herculis—A close binary star over the middle of the body; R. A. 16h. 35m. 15s., Dec. N. 31° 53′ 7″. A 3, yellowish white; B 6, orange tint. A "wonderous object"—one star being sometimes occulted by the other.

6. η Herculis—A bright star with a distant companion on the left thigh; R. A. 16h. 37m. 25s.; Dec. N. 39° 13′ 8″. A 3, pale yellow; B 10, dusky.

7. A large cluster on the left thigh, between ζ and η, 3½° southwesterly of the latter; R. A. 16h. 35m. 58s.; Dec. N. 36° 45′ 8″. A superb object, blazing up in the center, with numerous outlayers. Map IX., Fig. 53. May be seen by the naked eye in the absence of the moon.

8. A globular cluster of minute stars 1½° north by east of η; R. A. 17h. 12m. 14s.; Dec. N. 43° 18′ 4″. Large, bright, and resolvable, with a luminous centre. Several other stars in the field. Map IX., Fig. 54.

Telescopic Objects.—Alpha? Point out on the map Beta? Gamma? Delta? Zeta? Eta? What clusters? Point out on the map. What Nebula?

9. A small PLANETARY NEBULA between the hero's shoulders; R. A. 16h. 37m. 46s.; Dec. 24° 05′ 8″. A curious object, with a disc 8″ in diameter. Look northeast of γ and β in the left arm, to a point forming an equilateral triangle with these two stars.

10. A fine PLANETARY NEBULA near the right knee of Hercules; R. A. 16h. 43m. 23s. · Dec. N. 46° 47′ 0″. About 4° east by north from τ. It is large, round, and of a lucid pale blue hue. A 6th magnitude star near it somewhat eclipses its brightness.

SERPENTARIUS, VEL ÓPHIUCHUS (THE SERPENT BEARER).—MAP V.

206. THE SERPENT-BEARER is also called Æsculapius, or the god of medicine. He is represented as a man with a venerable beard, having both hands clenched in the folds of a prodigious serpent, which is writhing in his grasp.

The constellation occupies a considerable space in the mid-heaven, directly south of Hercules, and west of Taurus Poniatowski. Its center is very nearly over the equator, opposite to Orion, and comes to the meridian the 26th of July. It contains seventy-four stars, including one of the 2d magnitude, five of the 3d; and ten of the 4th.

207. The principal star in Serpentarius is called *Ras Alhague.* It is of the 2d magnitude, and situated in the head, about 5° E. S. E. of Ras Algethi, in the head of Hercules. Ras Alhague is nearly 13° N. of the equinoctial, while *Rho,* in the southern foot, is about 25° south of the equinoctial. These two stars serve to point out the extent of the constellation from north to south. Ras Alhague comes to the meridian on the 28th of July, about 21 minutes after Ras Algethi.

About 10° S. W. of Ras Alhague are two small stars of the 4th magnitude, scarcely more than a degree apart. They distinguish the left or west shoulder. The northern one is marked *Iota* and the other *Kappa.*

Eleven or twelve degrees S. S. E. of Ras Alhague are two other stars of the 3d magnitude, in the east shoulder, and about 2° apart. The upper one is called *Cheleb*, and the lower one *Gamma.* These stars in the head and shoulders of Serpentarius, form a triangle, with the vertex in Ras Alhague, and pointing toward the northeast.

208. About 4° E. of Gamma, is a remarkable cluster of four or five stars, in the form of the letter V, with the open part to the north. It very much resembles the Hyades. This beautiful little group mark the face of TAURUS PONIATOWSKI. The solstitial colure passes through the equinoctial about 2° E. of the

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206. What other name has the Serpent Bearer? How represented? Situation and extent? Number and size of its principal stars? 207. Name of its principal star? Magnitude and situation? Rho, and its situation? Use of these two stars? What said of Iota and Kappa? Of Cheleb and Gamma? 208. What remarkable cluster? For

lower star in the vertex of the V. The letter name of this star is *k*.

There is something remarkable in its central position. It is situated almost exactly in the mid-heavens, being nearly equidistant from the poles, and midway between the vernal and autumnal equinoxes. It is, however, about one and a third degrees nearer the north than the south pole, and about two degrees nearer the autumnal than the vernal equinox, being about two degrees west of the solstitial colure.

Directly south of the V, at the distance of about 12°, are two very small stars, about 2° apart, situated in the right hand, where it grasps the serpent. About half-way between, and nearly in a line with, the two in the hand and the two in the shoulder, is another star of the 3d magnitude, marked *Zeta*, situated in the Serpent, opposite the right elbow. It may be known by means of a minute star just under it.

Marsic, in the left arm, is a star of the 4th magnitude, about 10° S. W. of Iota and Kappa. About 7° farther in the same direction are two stars of the 3d magnitude, situated in the hand, and a little more than a degree apart. The upper one of the two, which is about 16° N. of Graffias in Scorpio, is called *Yed;* the other is marked Epsilon. These two stars mark the other point in the folds of the monster where it is grasped by Serpentarius.

The left arm of Serpentarius may be easily traced by means of the two stars in the shoulder, the one (Marsic) near the elbow, and the two in the hand; all lying nearly in a line N. N. E. and S. S. W. In the same manner may the right arm be traced, by stars very similarly situated; that is to say, first by the two in the east shoulder, just west of the V, thence 8° in a southerly direction inclining a little to the east, by Zeta, (known by a little star right under it,) and then by the two small ones in the right hand, situated about 6° below Zeta.

About 12° from Antares, in an easterly direction, are two stars in the right foot, about 2° apart. The largest and lower of the two, is on the left hand. It is of between the 3d and 4th magnitudes, and marked *Rho*. There are several other stars in this constellation of the 3d and 4th magnitudes. They may be traced out from the maps.

> "Thee, Serpentarius, we behold distinct,
> With *seventy-four* refulgent stars; and *one*
> Graces thy helmet, of the second class:
> The *Serpent*, in thy hand grasp'd, winds his spire
> Immense; fewer by *ten* his figure trace;
> *One* of the second rank; ten shun the sight;
> And seven, he who bears the monster hides."—*Eudosia*.

HISTORY.

This constellation was known to the ancients twelve hundred years before the Christian era. Homer mentions it. It is thus referred to in the Astronomicon of Manilius:—

> "Next, Ophiuchus strides the mighty snake,
> Untwists his winding folds, and smooths his back,
> Extends his bulk, and o'er the slippery scale
> His wide-stretch'd hands on either side prevail
> The snake turns back his head and seems to rage:
> That war must last where equal power prevails."

Æsculapius was the son of Apollo, by Coronis, and was educated by Chiron the Centaur in the art of medicine, in which he became so skilful, that he was considered the inventor and god of medicine. At the birth of Æsculapius, the inspired daughter of Chiron uttered, "in sounding verse," this prophetic strain.

> "Hail, great physician of the world, all hail!
> Hail, mighty infant, who, in years to come,
> Shall heal the nations and defraud the tomb!
> Swift be thy growth! thy triumphs unconfined!
> Make kingdoms thicker, and increase mankind:
> Thy daring art shall animate the dead,
> And draw the thunder on thy guilty head:
> Then shalt thou die, but from the dark abode
> Rise up victorious, and be twice a god."

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and resemblance? Marks what? What said of the lower star in the V.? What stars south of it? What of Marsic? Of Yed and Epsilon? How trace the left arm?

HISTORY.—Antiquity of this constellation? Proof? Who was Æsculapius? Account of his great skill? His metamorphosis? Remarkable fact respecting Socrates and Plato?

He accompanied the Argonauts to Colchis, in the capacity of physician. He is said to have restored many to life, insomuch that Pluto complained to Jupiter, that his dark dominion was in danger of being depopulated by his art.

Æsculapius was worshiped at Epidaurus, a city of Peloponnesus, and hence he is styled by Milton "the god in Epidaurus." Being sent for to Rome in the time of a plague, he assumed the form of a serpent and accompanied the ambassadors, but though thus changed, he was Æsculapius still, *in serpente deus*—the deity in a serpent—and under that form he continued to be worshiped at Rome. The cock and the serpent were sacred to him, especially the latter. The ancient physicians used them in their prescriptions.

One of the last acts of Socrates, who is accounted the wisest and best man of Pagan antiquity, was to offer a cock to Æsculapius. He and Plato were both idolaters; they conformed, and advised others to conform, to the religion of their country; to gross idolatry and absurd superstition. If the wisest and most learned were so blind, what must the foolish and ignorant have been?

TELESCOPIC OBJECTS.

1. α Ophiuchi (*Ras Alhague*)—A bright star with a minute companion, in the head of the figure; R. A. 17h. 27m. 30s.; Dec. N. 12° 40′ 08″. A 2, sapphire; B 9, pale grey. A coarse triplet of small stars near them.

2. δ Ophiuchi (*Yed*)—A star with a distant companion, in the right hand; R. A. 16h. 05m. 58s.; Dec. S. 3° 16′ 07″. A 3, deep yellow; B 10, pale lilac; a third minute star in the field.

3. η Ophiuchi—A brilliant star with a distant companion, on the left knee; on the margin of the milky way; R. A. 17h. 01m. 13s.; Dec. N. 15° 31′ 03″. A 2½, pale yellow; B 13, blue.

4. τ Ophiuchi—A close binary star on the left hand, 15° northeast of the bright star η, just described, towards Altair; R. A. 17h. 54m. 22s.; Dec. S. 8° 10′ 04″. A 5, and B 6, both pale white; C 10, light blue; two other stars in the field. Out of place on the map, or R. A. wrong in the tables, as given above.

5. A triple or rather multiple star, between the left foot of Ophiuchus, and the root of the tail of Scorpio; R. A. 17h. 05m. 29s.; Dec. S. 26° 21′ 05″. It is about 10° due east of Antares. A 4½, ruddy; B 6½, pale yellow; C 7½, greyish. The latter is double, a minute companion appearing at a distance, though not seen through ordinary instruments. For relative position, &c., see Map VIII., Fig. 14.

6. A fine globular cluster, between the right hip and elbow; R. A. 16h. 38m 56s.; Dec. S. 1° 40′ 03″. A rich cluster, condensed towards the center, with many straggling outlayers. About 8° from ε Ophiuchi, towards β.

7. A rich cluster of compressed stars, in the right hip; R. A. 16h. 48m. 45s.; Dec. S. 3° 51′ 08″. About 8° east of ε Ophiuchi; or half-way between β Libræ, and α Aquilæ. A beautiful round cluster, and may be seen with a telescope three feet in length.

8. A round cluster on the left leg; R. A. 17h. 09m. 42s.; Dec. S. 18° 20′ 07″. It lies about 3° southeast of ε, and rather more than ¼ the distance on a line from Antares tc Altair. A fine object—myriads of stars clustering to a blaze in the center.

9. A large globular cluster in the left arm; R. A. 17h. 29m. 13s.; Dec. S. 3° 09′ 01″. It lies 16° south of Ras Alhague, or about half way from β Scorpii to ε Aquilæ. 6½° south-by-west of γ Ophiuchi. A fine object, of a lucid white, and may be seen with small instruments. Several stars in the field. Map IX., Fig. 55.

Telescopic Objects.—Alpha? Delta? Eta? What multiple star? Point out on the map. What clusters? Which shown on the map?

CHAPTER X.

CONSTELLATIONS ON THE MERIDIAN IN AUGUST.

DRACO (THE DRAGON).—MAP VI.

209. THIS constellation, which compasses a large circuit in the polar regions by its ample folds and contortions, contains many stars which may be easily traced. From the head of the monster, which is under the foot of Hercules, there is a complete coil tending eastwardly, about 17° N. of Lyra; thence he winds down northerly about 14° to the second coil, where he reaches almost to the girdle of Cepheus; then he loops down somewhat in the shape of the letter U, and makes a third coil about 15° below the first. From the third coil he holds a westerly course for about 13°, then goes directly down, passing between the head of the Lesser and the tail of the Greater Bear.

210. Draco contains eighty stars, including two of the 2d magnitude, three of the 3d, and sixteen of the 4th.

> "The *Dragon* next, winds like a mighty stream:
> Within its ample folds are *eighty* stars,
> Four of the second order. Far he waves
> His ample spires, involving either *Bear*."

The head of the Dragon is readily distinguished by means of four stars, 3°, 4°, and 5° apart, so situated as to form an irregular square; the two upper ones being the brightest, and both of the 2d magnitude. The right-hand upper one, called *Etanin*, has been rendered very noted in modern astronomy from its connection with the discovery of a new law in physical science, called the *Aberration of Light*.

The letter name of this star is *Gamma*, or *Gamma Draconis;* and by this appellation it is most frequently called. The other bright star, about 4° from it on the left, is *Rastaben*.

211. About 4° W. of Rastaben, a small star may, with close attention, be discerned in the nose of the Dragon, which, with the irregular square before mentioned, makes a figure somewhat resembling an Italic *V*, with the point toward the west, and the open part toward the east. The small star in the nose, is called *Er Rakis*.

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209. Describe Draco—its situation and extent. 210. Number and size of its principal stars? How may the *head* of Draco be distinguished? What said of Etanin? Its letter name? What of Rastaben? 211. Of Er Rakis? Further of Rastaben? Of Etanin? Of Grumium? Of Omicron? How may the second coil be recognized? What of Zeta? Of Eta, Theta, and Asich? Of Thuban, Kappa, and Giansar?

The two small stars 5° or 6° S. of Rastaben are in the left foot of Hercules.

Rastaben is on the meridian nearly at the same moment with Ras Alhague. Etanin, 40° N. of it, is on the meridian about the 4th of August, at the same time with the three western stars in the face of Taurus Poniatowskii, or the V. It is situated less than 2° west o' the solstitial colure, and is exactly in the zenith of London. Its favorable position has led English astronomers to watch its appearance, for long periods, with the most exact and unwearied scrutiny.

Of the four stars forming the irregular square in the head, the lower and right-hand one is 5½° N. of Etanin. It is called *Grumium*, and is of the 3d magnitude. A few degrees E. of the square, may be seen, with a little care, eight stars of the 5th magnitude, and one of the 4th, which is marked *Omicron*, and lies 8° E. of Grumium. This group is in the first coil of the Dragon.

The second coil is about 13° below the first, and may be recognized by means of four stars of the 3d and 4th magnitudes, so situated as to form a small square, about half the size of that in the head. The brightest of them is on the left, and is marked Delta. A line drawn from Rastaben through Grumium, and produced about 14°, will point it out. A line drawn from Lyra through Zi Draconis, and produced 10° further, will point out *Zeta*, a star of the 3d magnitude, situated in the third coil. Zeta may otherwise be known, by its being nearly in a line with, and midway between, Etanin and Kochab. From Zeta, the remaining stars in this constellation are easily traced.

Eta, *Theta*, and *Asich*, come next; all stars of the 3d magnitude, and at the distance severally, of 6°, 4°, and 5° from Zeta. At Asich, the third star from Zeta, the tail of the Dragon makes a sudden crook. *Thuban*, *Kappa*, and *Giansar*, follow next, and complete the tail.

212. *Thuban* is a bright star of the 2d magnitude, 11° from Asich, in a line with, and about midway between, Mizar and the southernmost guard in the Little Bear. By nautical men this star is called the *Dragon's Tail*, and is considered of much importance at sea. It is otherwise celebrated as being formerly the *north polar star*. About 2,300 years before the Christian Era, Thuban was ten times nearer the true pole of the heavens than Cynosura now is.

Kappa is a star of the 3d magnitude, 10° from Alpha, between Megrez and the pole. Mizar and Megrez, in the tail of the Great Bear, form, with Thuban and Kappa, in the tail of the Dragon, a large quadrilateral figure, whose longest side is from Megrez to Kappa.

Giansar, the last star in the tail, is between the 3d and 4th magnitudes, and 5° from Kappa. The two pointers will also point out Giansar, lying at the distance of little more than 8° from them, and in the direction of the pole.

HISTORY.

Mythologists give various accounts of this constellation. By some it is represented as the watchful dragon which guarded the golden apples in the famous garden of the Hesperides, near Mount Atlas in Africa, and was slain by Hercules. Juno, who presented these apples to Jupiter on the day of their nuptials, took Draco up to heaven, and made a constellation of him, as a reward for his faithful services. Others maintain that in the war with the giants, this dragon was brought into combat, and opposed to Minerva, who seized it in her hand, and hurled it, twisted as it was, into the heavens round the axis of the world, before it had time to unwind its contortions, where it sleeps to this day. Other writers of antiquity say, that this is the dragon killed by Cadmus, who was ordered by his father to go in quest of his sister Europa, whom Jupiter had carried away, and never to return to Phenicia without her.

> "When now Agenor had his daughter lost,
> He sent his son to search on every coast;
> And sternly bade him to his arms restore
> The darling maid, or see his face no more."

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214. Size and position of Thuban? What called by nautical men? How otherwise celebrated? What further of Kappa, Mizar, Megrez, &c.?

HISTORY.—Various Mythological accounts? Story of Cadmus and the dragon's teeth?

His search, however, proving fruitless, he consulted the oracle of Apollo, and was ordered to build a city where he should see a heifer stop in the grass, and to call the country Bœotia. He saw the heifer according to the oracle, and as he wished to render thanks to the god by a sacrifice, he sent his companions to fetch water from the neighboring grove. The waters were sacred to Mars, and guarded by a most terrific dragon, who devoured all the messengers. Cadmus, tired of their seeming delay, went to the place, and saw the monster still feeding on their flesh.

Cadmus, beholding such a scene, boldly resolved to avenge, or to share their fate. He therefore attacked the monster with slings and arrows, and, with the assistance of Minerva, slew him. He then plucked out his teeth, and sowed them, at the command of Pallas, in a plain, when they suddenly sprung up into armed men.

Entertaining worse apprehension from the direful offspring than he had done from the dragon himself, he was about to fly, when they fell upon each other, and were all slain in one promiscuous carnage, except five, who assisted Cadmus to build the city of Bœotia.

TELESCOPIC OBJECTS.

1. α DRACONIS (*Thuban*)—A star with a distant companion in the fifth coil of Draco; R. A. 14h. 00m. 03s.; Dec. N. 65° 08′ 04″. A 3½, pale yellow; B 8, dusky; two other stars in the field. Upwards of 4,600 years ago, this was the pole-star of the Chaldeans.

2. β DRACONIS (*Rastaben*)—A star with a very distant companion, in the eye of Draco; R. A. 17h. 26m. 48s.; Dec. N. 52° 25′ 02″. A 2, yellow; B 10, bluish; other stars in field.

3. γ DRACONIS (*Etanin*)—A star with a telescopic companion, in the crown of Draco; R. A. 17h. 52m. 53s.; Dec. N. 51° 30′ 06″. A 2, orange tint; B 12, pale lilac. A third star in the field making a neat triangle with A and B. *Etanin* is celebrated as the star by viewing which, Bradly discovered the aberration of light in 1725. It is a zenith-star at the Greenwich observatory.

4. δ DRACONIS—A bright star with a distant companion, in the second flexure; R. A. 19h. 12m. 30s.; Dec. N. 67″ 22′ 08″. A 3, deep yellow; B 9½, pale red; other small stars in the field.

5. ε DRACONIS—A fine double star between the second and third flexures; R. A. 19h. 48m. 41s.; Dec. N. 69° 51′ 6″. A 5½, light yellow; B 8, blue; a third star just north of α.

6. η DRACONIS—A star with a companion, between the third and fourth flexures; R. A. 16h. 21m. 48s.; Dec. N. 61° 52′ 04″. A 3, deep yellow; B 11, pale grey.

7. μ DRACONIS—A very neat BINARY SYSTEM, on the tip of the Dragon's tongue; R. A. 17h. 02m. 02s.; Dec. N. 54° 41′ 02″. A 4, and B 4½, both white. Resembles Castor, though the components are nearer equal. Period, about 600 years.

8. A TRIPLE STAR in the first flexure; R. A. 18h. 21m. 36s.; Dec. N. 58° 42′ 05″. A 5, pale white; B 8½, light blue; C 7, ruddy. A difficult object—about midway between γ and δ.

9. A beautiful TRIPLE STAR in the nose of Draco, on a line from γ over β, and near twice as much further; R. A. 16h. 32m. 28s.; Dec. N. 53° 14′ 09″. A 6, pale yellow; B 6½, faint lilac; C 6, white; four other stars in view.

10. A BRIGHT-CLASS, OVAL NEBULA, under the body of Draco; R. A. 15h. 02m. 03s.; Dec. N. 56° 23′ 0″. Faint at the edges, with four stars in the field; one quite near it.

11. A PLANETARY NEBULA, between the second and third coil, on a line from Polaris to γ Draconis: R. A. 17h. 58m. 38s.; Dec. 66° 38′ 01″. A remarkably bright and pale blue object, with several telescopic stars in the field. Map IX., Fig. 56. It is situated exactly *in the pole of the ecliptic.*

LYRA (THE HARP).—MAP V.

213. This constellation is distinguished by one of the most brilliant stars in the northern hemisphere. It is situated directly south of the first coil of Draco, between the Swan on the

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TELESCOPIC OBJECTS.—Alpha? Beta? Gamma? Delta? Epsilon? Eta? Mu? Triple stars? Nebulæ?

213. How is Lyra distinguished? Where situated? Number and size of its principal stars?

east, and Hercules on the west; and when on the meridian, is almost directly overhead. It contains twenty-one stars, including one of the 1st magnitude, two of the 3d, and as many of the 4th.

> There *Lyra*, for the brightness of her stars,
> More than their number, eminent; thrice seven
> She counts, and *one* of these illuminates
> The heavens far around, blazing imperial
> In the *first* order."

214. This star "blazing imperial in the first order" is called *Vega*, and sometimes *Wega*; but more frequently, *Lyra*, after the name of the constellation.

There is no possibility of mistaking this star for any other. It is situated $14\frac{2}{3}°$ S. E. of Eltanin, and about 30° N. N. E. of Ras Alhague and Ras Algethi. It may be certainly known by means of two small, yet conspicuous stars, of the 5th magnitude, situated about 2° apart, on the east of it, and making with it a beautiful little triangle, with the angular point at Lyra.

The northernmost of these two small stars is marked *Epsilon*, and the southern one *Zeta*. About 2° S. E. of Zeta, and in a line with Lyra, is a star of the 4th magnitude, marked *Delta*, in the middle of the Harp; and 4° or 5° S. of Delta, are two stars of the 3d magnitude, about 2° apart, in the garland of the Harp, forming another triangle, whose vertex is in Delta. The star on the east is marked *Gamma*; that on the west, *Beta*. If a line be drawn from Etanin through Lyra, and produced 6° farther, it will reach Beta.

This is a variable star, changing from the 3d to nearly the 5th magnitude in the space of a week; it is supposed to have spots on its surface, and to turn on its axis, like our sun.

Gamma comes to the meridian 21 minutes after Lyra, and precisely at the same moment with *Epsilon*, in the tail of the Eagle, 17½° S. of it.

The remarkable brightness of α Lyra has attracted the admiration of astronomers in all ages. Manilius, who wrote in the age of Augustus, thus alludes to it :—

> "ONE, placed in front above the rest, displays
> A vigorous light and darts surprising rays."
>
> *Astronomicon*, B. i. p. 15.

HISTORY.

It is generally asserted that this is the celestial Lyre which Apollo or Mercury gave to Orpheus, and upon which he played with such a masterly hand, that even the most rapid rivers ceased to flow, the wild beasts of the forest forgot their wildness, and the mountains came to listen to his song.

Of all the nymphs who used to listen to his song, Eurydyce was the only one who made a deep impression on the musician, and their nuptials were celebrated. Their happiness, however, was short. Aristæus became enamored of Eurydice, and as she fled from her pursuer, a serpent, lurking in the grass, bit her foot, and she died of the wound. Orpheus resolved to recover her, or perish in the attempt. With his lyre in his hand, he entered the infernal regions, and gained admission to Pluto. The king of hell was charmed with his strains, the wheel of Ixion stopped, the stone of Sisyphus stood still, Tantalus forgot his thirst, and even the furies relented.

Pluto and Proserpine were moved, and consented to restore him Eurydice, provided he forbore looking behind till he had come to the extremest borders of their dark dominions.

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214. Names of the most brilliant star? How certainly known? Where are Epsilon, Zeta, Delta, Gamma, and Beta? What peculiarity about Beta? In α Lyræ?

The condition was accepted, and Orpheus was already in sight of the upper regions of the air, when he forgot, and turned back to look at his long-lost Eurydice. He saw her, but she instantly vanished from his sight. He attempted again to follow her, but was refused admission.

From this time, Orpheus separated himself from the society of mankind, which so offended the Thracian women, it is said, that they tore his body to pieces, and threw his head into the Hebrus, still articulating the words Eurydice! Eurydice! as it was carried down the stream into the Ægean sea. Orpheus was one of the Argonauts, of which celebrated expedition he wrote a poetical account, which is still extant. After his death, he received divine honors, and his lyre became one of the constellations.

This fable, or allegory, designed merely to represent the power of music in the hands of the great master of the science, is similarly described by three of the most renowned Latin poets. Virgil, in the fourth book of his Georgics, thus describes the effect of the lyre:—

"E'en to the dark dominions of the night
He took his way, through forests void of light,
And dared amid the trembling ghosts to sing,
And stood before the inexorable king.
The infernal troops like passing shadows glide,
And listening, crowd the sweet musician's side;
Men, matrons, children, and the unmarried maid,
The mighty hero's more majestic shade,
And youth, on funeral piles before their parents laid.
E'en from the depths of hell the damn'd advance;
The infernal mansions, nodding, seem to dance;
The gaping three-mouth'd dog forgets to snarl;
The furies hearken, and their snakes uncurl;
Ixion seems no more his pain to feel,
But leans attentive on his standing wheel.
All dangers past, at length the lovely bride
In safety goes, with her melodious guide."

Pythagoras and his followers represent Apollo playing upon a harp of seven strings, by which is meant (as appears from Pliny, b. ii. c. 22, Macrobius i. c. 19, and Censorius c. ii.), the sun in conjunction with the seven planets; for they made him the leader of that septenary chorus, and the moderator of nature, and thought that by his attractive force he acted upon the planets in the harmonical ratio of their distances.

The doctrine of celestial harmony, by which was meant the music of the spheres, was common to all the nations of the East. To this divine music Euripides beautifully alludes:—"Thee I invoke, thou self-created Being, who gave birth to Nature, and whom light and darkness, and the whole train of globes encircle with eternal music."—So also Shakspeare:—

———"Look, how the floor of heaven
Is thick inlaid, with patines of bright gold;
There's not the smallest orb which thou behold'st,
But in his motion like an angel sings,
Still quiring to the young-eyed cherubim:
Such harmony is in immortal souls;
But, while this muddy vesture of decay
Doth grossly close it in, we cannot hear it."

The lyre was a famous stringed instrument, much used among the ancients, said to have been invented by Mercury about the year of the world 2,000; though some ascribe the invention to Jubal. (Genesis iv. 21.) It is universally allowed, that the lyre was the first instrument of the string kind ever used in Greece. The different lyres, at various periods of time, had from four to eighteen strings each. The modern lyre is the Welsh harp. The lyre, among painters, is an attribute of Apollo and the Muses.

All poetry, it has been conjectured, was in its origin lyric; that is, adapted to recitation or song, with the accompaniment of music, and distinguished by the utmost boldness of thought and expression; being at first employed in celebrating the praises of gods and heroes.

Lesbos was the principal seat of the Lyric Muse; and Terpander, a native of this island, who flourished about 650 years B. C., is one of the earliest of the Lyric poets whose name we find on record. Sappho, whose misfortunes have united with her talents to render her name memorable, was born at Mitylene, the chief city of Lesbos. She was

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HISTORY.—Story of Orpheus and Eurydice? Design of this myth? Celebrated by what poets? Origin of the Lyre, and of Lyric poetry? What said of Pindar?

reckoned a tenth muse, and placed without controversy at the head of the female writers in Greece. But Pindar, a native of Thebes, who flourished about 500 years B. C., is styled the prince of lyric poets. To him his fellow-citizens erected a monument; and when the Lacedemonians ravaged Bœotia, and burnt the capital, the following words were written upon the door of the poet: FORBEAR TO BURN THIS HOUSE. IT WAS THE DWELLING OF PINDAR.

TELESCOPIC OBJECTS.

1. α LYRÆ—A star with a little companion; R. A. 18h. 31m. 30s.; Dec. N. 38° 38′ 01″. A 1, pale sapphire; B 11, smalt blue. Map VIII., Fig. 15.

α Lyria is computed to be 400,000 times as remote as our sun; or 38,000,000,000,000 distant! And yet what is this to the mean distances of many of those of the 12th to 15th magnitudes?

2. β LYRÆ—A star with its companions forming a quadruple system; R. A. 18h. 44m. 09s.; Dec. N. 33° 10′ 08″. A 3, very white and splendid; B 8, pale grey; C 8½, faint yellow; D 9, light lilac. β is regarded as variable.

3. γ LYRÆ—A lustrous star 7° southeast of Vega, with a minute distant companion R. A. 18h. 52m. 57s.; Dec. N. 32° 28′ 05″. A 3, bright yellow; B 11, blue; other telescopic stars in the field.

4. ε LYRÆ—A splendid MULTIPLE STAR, only 1½° northeast of Vega; R. A. 18h. 39m. 02s.; Dec. N. 39° 30′ 03″. Map VIII., Fig. 16. With small instruments it appears simply double; but with better instruments each of the components are found to be double, and binary systems. Between the twin systems are three minute stars. The components of the two systems are described as A 5, yellow; B 6½, ruddy; C 5, and D 5½, both white. A, B are the lowest, or northern pair.

These two twin systems are in motion around a common center of gravity, as well as the respective components around each other. The period of the individual systems is estimated at about 2,000 years; while 1,000,000 of years are supposed to be requisite for a revolution round the common center of both!

5. ζ LYRÆ—A fine DOUBLE STAR about 2° south of ε; R. A. 18h. 39m. 15s.; Dec. N. 37° 26′ 05″. A 5, topaz; B 5½, greenish.

6. η LYRÆ—A neat DOUBLE STAR 6° east of Vega; R. A. 19h. 08m. 18s.; Dec. N. 38° 52 05″. A 5, sky blue; B 9, violet tint. A fine object for a moderate telescope.

7. ν LYRÆ—A QUADRUPLE STAR in the cross-piece of the Lyre; R. A. 18h. 43m. 48s.; Dec. N. 32° 38′ 0″. A 9, pale yellow; B 13, bluish; C 11, pale blue; D 15, blue; three other stars in the field. A very delicate object.

8. A GLOBULAR CLUSTER, in a splendid field, between the eastern yoke of Lyra and the head of Cygnus; R. A. 19h. 10m. 19s.; Dec. N. 29° 54′ 02″. About 5½° southeast of β Lyræ, towards β Cygni, and 3½° from the latter. Map IX., Fig. 57.

9. An ANNULAR NEBULA between β and γ; R. A. 18h. 47m. 37s.; Dec. N. 32° 50′ 01″. A wonderful object, in the form of an elliptical ring. Supposed by Herschel to be 900 times as distant as Sirius. A clear opening through its center, and several stars in the field. Map IX., Fig. 58.

TAURUS PONIATOWSKII.—MAP V.

215. This small asterism is between the shoulder of Ophiuchus and the Eagle. The principal stars are in the head, and of the 4th magnitude. They are arranged in the form of the letter V, and from a fancied resemblance to the zodiac Bull, and the Hyades, became another Taurus. See description of Serpentarius, article 206.

TELESCOPIC OBJECTS.—Alpha? Beta? Gamma? Epsilon? Point out on the map. Zeta? Eta? Nu? What cluster? Point out on the map. What nebula, and where found on the map?

215. Describe Taurus Poniatowskii. Where situated?

TELESCOPIC OBJECTS.

1. A neat DOUBLE STAR in the space between the Polish Bull, and the Eagle's wing, 8° east of α Ophiuchi, in a line towards Altair; R. A. 17h. 58m. 17s.; Dec. N. 11° 59′ 08″. A 8, straw-color; B 8½, sapphire blue.

2. A fine PLANETARY NEBULA, in a rich vicinity, in the shoulder; R. A. 18h. 04m. 21s.; Dec. N. 6° 49′ 02″. A small but bright object, regarded by Prof. Struve as one of the most curious in the heavens. Many telescopic stars in the field.

SCUTUM SOBIESKI (SOBIESKI'S SHIELD).—MAP V.

216. This small figure is between the head of the Polish Bull, and the head of Sagittarius. Its four principal stars are of the 5th magnitude; and it is important chiefly for its Telescopic Objects.

TELESCOPIC OBJECTS.

1. A DOUBLE STAR 1½° northeast of μ Sagittarii; R. A. 18h. 07m. 37s.; Dec. S. 19° 55′ 05″. A 8½, and B 10, both grey.

2. A neat DOUBLE STAR, in a long and straggling assemblage below the Shield; R. A. 18h. 10m. 36s.; Dec. S. 17° 11′ 07″. A 9, and B 11, both bluish. It is 4° from μ Sagittarii, in a very rich vicinity; several splendid fields lying only about 1° south of it.

3. A BEAUTIFUL CLUSTER below the base of the Shield; R. A. 18h. 08m. 49s.; Dec. S. 18° 27′ 05″. A line from α Aquilæ, southwest over λ Antinoi, and continued as far again, will reach this object.

4. A SCATTERED BUT LARGE CLUSTER, north-half-east from μ Sagittarii 7°; R. A. 18h. 09m. 44s.; Dec. S. 13° 50′ 05″. Stars disposed in pairs, the whole forming a very pretty object in a telescope of tolerable capacity.

5. A HORSE-SHOE NEBULA just below the Shield; R. A. 18h. 11m. 23s.; Dec. S. 16° 15′ 08″. It has been compared to a Greek Ω. Map IX., Fig. 59. Five stars in the object, and others in the field, and the region around it particularly rich. Sir William Herschel computed that there were 285,000 stars in a space 10° long, and 2½° wide; many of which were 2,300 times as far off as Sirius!

SAGITTARIUS (THE ARCHER).—MAP V.

217. This is the ninth sign and the tenth constellation of the Zodiac. It is situated next east of Scorpio, with a mean declination of 35° S., or 12° below the ecliptic. The sun enters this *sign* on the 22d of November, but does not reach the *constellation* before the 7th of December. It occupies a considerable space in the southern hemisphere, and contains a number of subordinate, though very conspicuous stars. The whole number of its visible stars is sixty-nine, including five of the 3d magnitude, and ten of the 4th.

TELESCOPIC OBJECTS.—What double star? What nebula?
216. Situation and components of Scotum Sobieski? For what chiefly important?
TELESCOPIC OBJECTS.—What double stars? Clusters? Nebula?
217. Order of Sagittarius, in the signs and constellations? When does the sun enter this *sign?* The *constellation?* Its extent? Number and size of its stars?

218. Sagittarius may be readily distinguished by means of five stars of the 3d and 4th magnitudes, forming a figure resembling a little, short, straight-handled dipper, turned nearly bottom upward, with the handle to the west, familiarly called the *Milk-Dipper*, because it is partly in the Milky-Way.

This little figure is so conspicuous that it cannot easily be mistaken. It is situated about 33° E. of Antares, and comes to the meridian a few minutes after Lyra, on the 17th of August. Of the four stars forming the bowl of the Dipper, the two upper ones are only 3° apart, and the lower ones 5°.

The two smaller stars forming the handle, and extending westerly about 4½°, and the easternmost one in the bowl of the Dipper, are all of the 4th magnitude. The star in the end of the handle, is marked *Lambda*, and is placed in the bow of Sagittarius, just within the Milky-Way. Lambda may otherwise be known by its being nearly in a line with two other stars about 4½° apart, extending toward the S. E. It is also equidistant from *Phi* and *Delta*, with which it makes a handsome triangle, with the vertex in Lambda. About 5° above Lambda, and a little to the west, are two stars close together in the end of the bow, the brightest of which is of the 4th magnitude, and marked *Mu*. This star serves to point out the winter solstice, being about 2° N. of the tropic of Capricorn, and less than one degree east of the solstitial colure.

If a line be drawn from Sigma through Phi, and produced about 6° farther to the west, it will point out *Delta*, and produced about 3° from Delta, it will point out *Gamma;* stars of the 3d magnitude, in the arrow. The latter is in the point of the arrow, and may be known by means of a small star just above it, on the right. This star is so nearly on the same meridian with Etanin, in the head of Draco, that it culminates only two minutes after it.

A few other conspicuous stars in this constellation, forming a variety of geometrical figures, may be easily traced from the map.

HISTORY.

This constellation, it is said, commemorates the famous Centaur Chiron, son of Philyra and Saturn, who changed himself into a horse, to elude the jealous inquiries of his wife Rhea.

Chiron was famous for his knowledge of music, medicine and shooting. He taught mankind the use of plants and medicinal herbs; and instructed, in all the polite arts, the greatest heroes of the age. He taught Æsculapius physic, Apollo music, and Hercules astronomy; and was tutor to Achilles, Jason, and Æneas. According to Ovid, he was slain by Hercules, at the river Evenus, for offering indignity to his newly married bride.

"Thou monster double shap'd, my right set free—
Swift as his words, the fatal arrow flew;
The Centaur's back admits the feather'd wood,
And through his breast the barbed weapon stood;
Which, when in anguish, through the flesh he tore,
From both the wounds gush'd forth the spumy gore."

The arrow which Hercules thus sped at the Centaur, having been dipped in the blood of the Lernæan Hydra, rendered the wound incurable, even by the father of medicine himself, and he begged Jupiter to deprive him of immortality, if thus he might escape his excruciating pains. Jupiter granted his request, and translated him to a place among the constellations.

"Midst golden stars he stands refulgent now,
And thrusts the Scorpion with his bended bow."

This is the Grecian account of Sagittarius; but as this constellation appears on the ancient zodiacs of Egypt, Dendera, Esne, and India, it seems conclusive that the Greeks

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218. How distinguished? Where is Lambda? How known? Where are Mu, Delta, and Gamma?

HISTORY.—What does Sagittarius commemorate? Story of Chiron? What said of the antiquity of this constellation?

only *borrowed the figure*, while they *invented the fable*. This is known to be true with respect to very many of the ancient constellations. Hence the jargon of the conflicting accounts which have descended to us.

TELESCOPIC OBJECTS.

1. μ SAGITTARII—A MULTIPLE STAR in the north end of the Archer's bow; R. A. 18h. 04m. 11s.; Dec. S. 21° 05′ 07″ About 25° east-northeast of Antares. A 3½, pale yellow; B 16, blue; C 9½, and D 10, both reddish.

2. σ SAGITTARII—A star with a distant companion in the Archer's right shoulder; R. A. 18h. 45m. 20s.; Dec. S. 26° 29′ 03″. A 3, ruddy; B 9½, ash-colored.

3. A very delicate TRIPLE STAR, between the heads of Sagittarius and Capricorn, about 25° south-by-west of Altair, and 10° west of β Capricorni; R. A. 19h. 31m. 33s.; Dec. S. 16° 39′ 02″. A 5½, yellow; B 8, violet; C 16, blue. Other small stars in the field.

4. A LARGE AND COARSE CLUSTER of minute stars, close to the upper end of the bow, and in the Galaxy; R. A. 18h. 03m. 08s.; Dec. S. 21° 36′ 01″. Stars of the 10th to 13th magnitudes. A rich field of no particular form.

5. A LOOSE CLUSTER in the Galaxy, between the Archer's head and Sobieski's Shield; R. A. 18h. 22m. 14s.; Dec. S. 19° 10′ 02″. The most prominent are a pair of 8th magnitude stars. It is about 5° northeast of μ Sagittarii.

6. A FINE GLOBULAR CLUSTER between the head and bow, near the solsticial colure; R. A. 18h. 26m. 25s.; Dec. S. 24° 01′ 04″. A fine group, compressed towards the center, with several single stars in the field. Map IX., Fig. 60.

CORONA AUSTRALIS (THE SOUTHERN CROWN).—MAP V.

219. This is a small and unimportant constellation near the fore-legs of Sagittarius; and between them and the Milky-Way. R. A. about 18h. 44m.; Dec. S. 40°. Its four principal stars are of the 5th magnitude, situated near each other, and arranged in a gentle curve line, lying north and south. It has no Mythological History, or Telescopic Objects worthy of notice.

AQUILA ET ANTINOUS (THE EAGLE AND ANTINOUS).—MAP V.

220. This double constellation is situated directly south of the Fox and Goose, and between Taurus Poniatowskii on the west, and the Dolphin on the east. It contains seventy-one stars, including one of the 1st magnitude, nine of the 3d, and seven of the 4th. It may be readily distinguished by the position and superior brilliancy of its principal star.

221. *Altair*, the principal star in the Eagle, is of the 1st, or between the 1st and 2d magnitudes. It is situated about 14°

TELESCOPIC OBJECTS.—Mu? Sigma? What triple star? What clusters? Which shown on the map? Point it out.

219. Describe Corona Australis. Its principal stars? History and Telescopic Objects?
220. Situation of Aquila and Antinous? Number and size of its principal stars?
221. Altair—how known? Stars each side of it? Use of Altair in navigation? What

S. W. of the Dolphin. It may be known by its being the largest and middle one of the three bright stars which are arranged in a line bearing N. W. and S. E. The stars on each side of Altair are of the 3d magnitude, and distant from it about 2°. This row of stars very much resembles that in the Guards of the Lesser Bear.

Altair is one of the stars from which the moon's distance is taken for computing longitude at sea. Its mean declination is nearly $8\frac{1}{2}$° N., and when on the meridian, it occupies nearly the same place in the heavens that the sun does at noon on the 12th day of April. It culminates about 6 minutes before 9 o'clock, on the last day of August. It rises *acronically* about the beginning of June.

Ovid alludes to the rising of this constellation; or, more probably, to that of the principal star, Altair :—

——————"Now view the skies,
And you'll behold Jove's hook'd-bill bird arise."
Massey's Fasti.

——————"Among thy splendid group
One dubious whether of the Second rank,
Or to the First entitled; but whose claim
Seems to deserve the First."
Eudosia.

The northernmost star in the line, next above Altair, is called *Tarazed.* In the wing of the Eagle, there is another row composed of three stars, situated 4° or 5° apart, extending down toward the southwest; the middle one in this line is the smallest, being only of the fourth magnitude; the next is of the 3d magnitude, marked *Delta*, and situated 8° S. W. of Altair.

As you proceed from Delta, there is another line of three stars of the 3d magnitude, between 5° and 6° apart, extending southerly, but curving a little to the west, which mark the youth Antinous. The northern wing of the Eagle is not distinguished by any conspicuous stars.

Zeta and *Epsilon*, of the 3d magnitude, situated in the tail of the Eagle, are about 2° apart, and 12° N. W. of Altair. The last one in the tail, marked Epsilon, is on the same meridian, and culminates the same moment with Gamma, in the Harp.

From Epsilon, in the tail of the Eagle, to Theta, in the wrist of Antinous, may be traced a long line of stars, chiefly of the 3d magnitude, whose letter names are Theta, Eta, Mu, Zeta and Epsilon. The direction of this line is from S. E. to N. W., and its length is about 25°.

Eta is remarkable for its *changeable* appearance. Its greatest brightness continues but 40 hours; it then gradually diminishes for 66 hours, when its luster remains stationary for 30 hours. It then waxes brighter and brighter, until it appears again as a star of the 3d magnitude.

From these phenomena, it is inferred that it not only has spots on its surface, like our sun, but that it also turns on its axis.

Similar phenomena are observable in Algol, Beta, in the Hare, Delta, in Cepheus, and Omicron, in the Whale, and many others.

——————"Aquila the next,
Divides the ether with her ardent wing:
Beneath the *Swan* nor far from *Pegasus*,
Poetic Eagle."

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poetic quotation? Where are Tarazed and Delta? Zeta and Epsilon? Theta? Eta? For what remarkable?

HISTORY.

Aquila, or the Eagle, is a constellation usually joined with Antinous. Aquila is supposed to have been Merops, a king of the island of Cos, in the Archipelago, and the husband of Clymene, the mother of Phæton; this monarch having been transformed into an eagle, and placed among the constellations. Some have imagined that Aquila was the eagle whose form Jupiter assumed when he carried away Ganymede; others, that it represents the eagle which brought nectar to Jupiter while he lay concealed in the cave at Crete, to avoid the fury of his father, Saturn. Some of the ancient poets say, that this is the eagle which furnished Jupiter with weapons in his war with the giants:—

"The towering *Eagle* next doth boldly soar,
As if the thunder in his claws he bore;
He's worthy Jove, since he, a bird, supplies
The heaven with sacred bolts, and arms the skies."
Manilius.

The eagle is justly styled the "sovereign of birds," since he is the largest, strongest, and swiftest of all the feathered tribe that live by prey. Homer calls the eagle, "the strong sovereign of the plumy race;" Horace styles him—

"The royal bird, to whom the king of heaven
The empire of the feathered race has given:"

And Milton denominates the eagle the "Bird of Jove." Its sight is quick, strong and piercing, to a proverb: Job xxix., 28, &c.

"Though strong the hawk, though practised well to fly,
An eagle drops her in the lower sky;
An eagle when deserting human sight.
She seeks the sun in her unwearied flight;
Did thy command her yellow pinion lift
So high in air, and set her on the clift
Where far above thy world she dwells alone,
And proudly makes the strength of rocks her own;
Thence wide o'er nature takes her dread survey,
And with a glance predestinates her prey?
She feasts her young with blood; and hovering o'er
The unslaughtered host, enjoys the promised gore."

ANTINOUS.

Antinous is a part of the constellation Aquili, and was invented by Tycho Brahe Antinous was a youth of Bithynia, in Asia Minor. So greatly was his death lamented by the emperor Adrian, that he erected a temple to his memory, and built in honor of him a splendid city, on the banks of the Nile, the ruins of which are still visited by travelers with much interest.

TELESCOPIC OBJECTS.

1. α Aquilæ (*Altair*)—A bright star in the neck, with a distant companion; R. A. 19h. 42m. 58s.; Dec. N. 8° 26′ 09″. A 1½, pale yellow; B 10, violet tint.

2. β Aquilæ (*Alshain*)—A double star, also in the neck of Aquila, and the head of Antinous; R. A. 19h. 47m. 26s.; Dec. N. 6° 00′ 07″. About 2½° south-southeast of Altair. A 3½, pale orange; B 10, pale grey; with other stars in the field.

3. γ Aquilæ (*Tarazed*)—A star in the back of Aquila, on a line with α and β, with a minute companion; R. A. 19h. 38m. 38s.; Dec. N. 10° 13′ 06″. A 3, pale orange; B 12, dusky; other stars around.

4. δ Aquilæ, in the southern wing; R. A. 19h. 17m. 25s.; Dec. N. 2° 48′ 00″. Has a distant companion. A 3½, white; B 12, livid; other stars in the field.

5. ξ Aquilæ, in the tail; R. A. 18h. 58m. 02s.; Dec. N. 13° 37′ 08″. A 3, greenish tint; B 11, livid; two other stars in the field.

6. A neat double star on the margin of the lower wing; R. A. 18h. 57m. 59s.; Dec. N. 6° 18′ 08″. A 7½, lucid white; B 9, cerulean blue. A fine object, not difficult to find, as

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History.—Different suppositions respecting? Manilius? Horace? Milton? What said of Antinous?

Telescopic Objects.—Alpha? Beta? Gamma? Delta? Xi? Other double stars? What clusters? Which shown on the map? What nebula?

it lies 10° due north of λ Antinoi, a 3d magnitude star, and 13° west of β Aquilæ. The brightest object of its immediate neighborhood.

7. A WIDE DOUBLE STAR about 4° west-by-south of λ Antinoi, between the foot and Sobieski's Shield; R. A. 18h. 41m. 07s.; Dec. S. 6° 05′ 03″. A 7, orange tint; B 9, cerulean blue. Many telescopic stars in the field.

8. A SPLENDID CLUSTER close to the southeast of the last described object; R. A. 18h. 42m. 32s.; Dec. S. 6° 27′ 02″. It is between the left foot and Sobieski's Shield. A gorgeous object "somewhat resembling a flight of wild ducks in shape," has an 8th magnitude star in the middle, and two larger east of it; probably all three between us and the cluster. Map IX., Fig. 61.

9. A LOOSE CLUSTER between the lower wing and the leg of Antinous, and 13° southwest of Altair, on a line from Vega through ε Aquilæ; R. A. 19h. 08m. 36s.; Dec. S. 1° 11′ 09″ A splashy group of stars from the 9th to the 12th magnitudes, on the eastern margin of the Galaxy.

10. A STELLAR NEBULA on the Eagle's back, about 5° west of Altair; R. A. 19h. 23m. 55s.; Dec. N. 8° 54′ 01″. A minute object in the Milky-Way; and in the most powerful telescopes, fan-shaped.

SAGITTA (THE ARROW.)—MAP V.

222. SAGITTA is a small but old constellation between the Fox and Goose on the north, and the Eagle on the south. Its two principal stars are of the 4th magnitude, and lie nearly east and west, about 4° apart. The next two largest stars are of the 5th magnitude.

TELESCOPIC OBJECTS.

1. ε SAGITTÆ—A star with a distant companion about 8° north-northwest of Altair, on a line towards Vega; R. A. 19h. 30m. 03s.; Dec. N. 16° 06′ 5″. A 6, pale white; B 8, light blue.

2. ζ SAGITTÆ—A neat DOUBLE STAR just above the Arrow, 9° south by east from β Cygni, and 10° north of Altair; R. A. 19h. 41m. 53s.; Dec. N. 18° 44′ 8″. A 5, silvery white; B 9, blue.

3. ϑ SAGITTÆ—A TRIPLE STAR near the head of the Arrow, about half-way from β Cygni to α Delphini; R. A. 20h. 02m. 53s.; Dec. N. 20° 26′ 6″. A 7, pale topaz; B 9, grey; C 8, pearly yellow.

4. A RICH COMPRESSED CLUSTER on the shaft of the arrow, 10° northeast of Altair; R. A. 19h. 46m. 36s.; Dec. N. 18° 22′ 1″. Telescopic stars around it.

ANSER ET VULPECULA (THE FOX AND GOOSE).—MAP V.

223. This is a modern constellation, situated between the Swan on the north, and the Arrow or the Dolphin and Eagle on the south. It is composed of some thirty stars, the largest of which is of the 3d magnitude.

TELESCOPIC OBJECTS.

1. A star with a distant companion on the nose of Reynard, and neck of the Goose, 8½° south of β Cygni; R. A. 19h. 22m. 03s.; Dec. N. 24° 20′ 7″.

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222. Describe Sagitta—its principal stars.
TELESCOPIC OBJECTS.—Epsilon? Zeta? What triple star? Cluster?
223. Describe the Fox and Goose. Its component stars?

2. A WIDE DOUBLE STAR, 11½° north of Altair, between the Fox and the Arrow, in the eastern edge of the Galaxy; R. A. 19h. 46m. 20s.; Dec. N. 19° 55′ 5″. A and B both 7 and both white.

3. A LARGE STRAGGLING CLUSTER on the neck of the Goose, and about 3° from β Cygni; R. A. 19h. 20m. 30s.; Dec. N. 24° 49′ 3″. Two 7th magnitude stars in the west. The cluster has the form of a Greek Ω.

4. The celebrated DUMB-BELL NEBULA, on the Fox's breast, about 7° southeast of Cygni, and nearly half-way between it and the Dolphin; R. A. 19h. 52m. 39s.; Dec. N. 22° 17′ 1″. (Map IX., Fig. 62.) This magnificent and singular object is in a crowded vicinity, where field after field is very rich.

CHAPTER XI.

CONSTELLATIONS ON THE MERIDIAN IN SEPTEMBER.

DELPHINUS (THE DOLPHIN).—MAP V.

224. THIS beautiful little cluster of stars is situated 13° or 14° N. E. of the Eagle. It consists of eighteen stars, including four of the 3d magnitude, but none larger. It is easily distinguished from all others, by means of the four principal stars in the head, which are so arranged as to form the figure of a diamond, pointing N. E. and S. W. To many, this cluster is known by the name of *Job's Coffin;* but from whom, or from what fancy, it first obtained this appellation, is not known.

225. There is another star of the 3d magnitude, situated in the body of the Dolphin, about 3° S. W. of the Diamond, and marked *Epsilon.* The other four are marked *Alpha*, *Beta*, *Gamma*, *Delta.* Between these are several smaller stars, too small to be seen in presence of the moon.

The mean declination of the Dolphin is about 15° N. It comes to the meridian the same moment with Deneb Cygni, and about 50 minutes after Altair, on the 16th of September.

> "Thee I behold, majestic *Cygnus*,
> On the marge dancing of the heavenly sea,
> Arion's friend; eighteen thy stars appear—
> *One* telescopic."

TELESCOPIC OBJECTS.—What double stars? Cluster? Nebula? Point out on the map.
224. Constellations in this chapter? Delphinus? Number and size of stars? How distinguished? What other name has this constellation? 225. Where are Epsilon, Alpha, Beta, Gamma and Delta? Mean declination, &c.

HISTORY.

The Dolphin, according to some mythologists, was made a constellation by Neptune because one of these beautiful fishes had persuaded the goddess Amphitrite, who had made a vow of perpetual celibacy, to become the wife of that deity; but others maintain, that it is the dolphin which preserved the famous lyric poet and musician Arion, who was a native of Lesbos, an island in the Archipelago.

He went to Italy with Periander, tyrant of Corinth, where he obtained immense riches by his profession. Wishing to revisit his native country, the sailors of the ship in which he embarked resolved to murder him, and get possession of his wealth. Seeing them immovable in their resolution, Arion begged permission to play a tune upon his lute before he should be put to death. The melody of the instrument attracted a number of dolphins around the ship; he immediately precipitated himself into the sea; when one of them, it is asserted, carried him safe on his back to Tænarus, a promontory of Laconia, in Peloponnesus; when he hastened to the court of Periander, who ordered all the sailors to be crucified at their return.

> "But (past belief), a dolphin's arched back
> Preserved Arion from his destined wrack;
> Secure he sits, and with harmonious strains
> Requites his bearer for his friendly pains."

When the famous poet Hesiod was murdered in Naupactum, a city of Ætolia, in Greece, and his body thrown into the sea, some dolphins, it is said, brought back the floating corpse to the shore, which was immediately recognized by his friends; and the assassins being afterwards discovered by the dogs of the departed bard, were put to death by immersion in the same sea.

Taras, said by some to have been the founder of Tarentum, now Tarento, in the south of Italy, was saved from shipwreck by a dolphin; and the inhabitants of that city preserved the memory of this extraordinary event on their coin.

The natural shape of the dolphin, however, is not incurvated, so that one might ride upon its back, as the poets imagined, but almost straight. When it is first taken from the water, it exhibits a variety of exquisitely beautiful but evanescent tints of color, that pass in succession over its body until it dies. They are an extremely swift-swimming fish, and are capable of living a long time out of water; in fact, they seem to delight to gambol, and leap out of their native element.

> "Upon the swelling waves the dolphins show
> Their bending backs; then swiftly darting go,
> And in a thousand wreaths their bodies show."

TELESCOPIC OBJECTS.

1. α Delphini—A bright star with a distant telescopic companion; R. A. 20h. 32m. 12s.; Dec. N. 15° 21′ 01″. A 3½, pale white; B 13, blue.

2. β Delphini—A delicate triple star on the Dolphin's body, 1½° south-by-west of α, in a line with β Cygni and γ Lyræ; R. A. 20h. 30m. 03s.; Dec. N. 14° 02′ 06″. A 4, greenish tinge; B 15, and C 12, both disky.

3. γ Delphini—A beautiful double star in the head, 2° east of α; R. A. 20h. 39m. 15s.; Dec. N. 15° 33′ 02″. A 4, yellow; B 7, light emerald, with a third star about 2″ distant.

4. A delicate quadruple star, near ε in the tail; R. A. 20h. 23m. 35s.; Dec. N. 10° 43′ 06″. A 7½, and B 8, both white; C 16, blue; D 9, yellowish; several other small stars in the field. Map VIII., Fig. 17.

5. A small bright cluster, in the Dolphin's tail, 3½° south of ε; R. A. 20h. 26m. 21s.; Dec. N. 6° 53′ 02″. Just east of a 9th magnitude star—a coarse telescopic pair at a distance, and several minute stars in the field.

6. A small planetary nebula, betwen the pectoral fin and the arrow head, 6° north-northwest of α, and exactly on a line towards Vega Lyræ; R. A. 20h. 15m. 15s.; Dec. N 19° 35, 06″. It is in a coarse cluster, in the center of which are four conspicuous stars.

History.—Accounts of the origin of Delphinus? What said of Hesiod? Of Taras? Of the natural shape, &c.?

Telescopic Objects.—Alpha? Beta? Gamma? What quadruple star? Point out on the map. What cluster? Nebula?

CYGNUS (THE SWAN).—MAP V.

226. This remarkable constellation is situated in the Milky-Way, directly E. of Lyra, and nearly on the same meridian with the Dolphin. It is represented on outspread wings, flying down the Milky-Way, toward the southwest.

The principal stars which mark the wings, the body and the bill of Cygnus, are so arranged as to form a large and regular *Cross;* the upright piece lying along the Milky-Way from N. E. to S. W., while the *cross piece,* representing the wings, crosses the other at right angles, from S. E. to N. W.

227. *Arided* or *Deneb Cygni,* in the body of the Swan, is a star of the second magnitude, 24° E. N. E. of Lyra, and 30° directly N. of the Dolphin. It is the most brilliant star in the constellation. It is situated at the upper end of the cross, and comes to the meridian at 9 o'clock on the 16th of September.

Sad'r is a star of the 3d magnitude, 6° S. W. of Deneb, situated exactly in the cross, or where the upright piece intersects the cross piece, and is about 20° E. of Lyra.

Delta, the principal star in the west wing, or arm of the cross, is situated N. W. of Sad'r, at the distance of little more than 8°, and is of the 3d magnitude. Beyond Delta, toward the extremity of the wing, are two smaller stars about 5° apart, and inclining a little obliquely to the north; the last of which reaches nearly to the first coil of Draco. These stars mark the west wing; the east wing may be traced by means of stars very similarly situated.

Gienah is a star of the 3d magnitude, in the east wing, just as far east of Sad'r in the center of the cross, as Delta is west of it. This row of three equal stars, Delta, Sad'r and Gienah, form the bar of the cross, and are equi-distant from each other, being about 8° apart. Beyond Gienah on the east, at the distance of 6° or 7°, there are two other stars of the 3d magnitude; the last of which marks the extremity of the eastern wing.

The stars in the neck are all too small to be noticed. There is one, however, in the beak of the Swan, at the foot of the cross, called *Albireo,* which is of the 3d magnitude, and can be seen very plainly. It is about 16° S. W. of Sad'r, and about the same distance S. E. of Lyra, with which it makes nearly a right angle.

"In the small space between Sad'r and Albireo," says Dr. Herschel, "the stars in the Milky-Way seem to be clustering into two separate divisions; each division containing more than *one hundred and sixty-five thousand stars.*"

Albireo bears northerly from Altair, about 20°. Immediately south and southeast of Albireo, may be seen the Fox and GOOSE; and about midway between Albireo and Altair, there may be traced a line of four or five minute stars, called the ARROW; the head of which is on the S. W., and can be distinguished by means of two stars situated close together.

228. According to the British catalogue, this constellation contains eighty-one stars, including one of the 1st or 2d magnitude, six of the 3d, and twelve of the 4th. The author of the following beautiful lines says there are one hundred and seven.

"Thee, silver Swan, who, silent, can o'erpass?
A *hundred* with *seven* radiant stars compose
Thy graceful form: amid the lucid stream

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226. Situation of Cygnus? How represented? Figure made by its principal stars? Its position? 227. Which is the brightest of its stars? Describe Sad'r, Delta, Gienah, Albireo. Remark of Dr. Herschel? 228. Number of stars in Cygnus? Variable stars? What are they supposed to indicate?

Of the fair Milky-Way distinguished: *one*
Adorns the *second* order, where she cuts
The waves that follow in her utmost track;
This never hides its fire throughout the night,
And of the rest, the more conspicuous mark
Her snowy pinions and refulgent neck."—*Eudosia*, b. iv.

Astronomers have discovered *three variable* stars in the Swan. *Chi*, situated in the neck, between Beta and Sad'r, was first observed to vary its brightness in 1686. Its periodical changes of light are now ascertained to be completed in 405 days. *Sad'r* is also changeable. Its greatest luster is somewhat less than that of a star of the 3d magnitude and it gradually diminishes till it reaches that of the 6th. Its changes are far from bein regular, and, from present observations, they do not seem to recur till after a period o ten years or more.

A third variable star was discovered in the head on the 20th of June, 1670, by Anthelme. It appeared then to be of the 3d magnitude, but was so far diminished in the followin October, as to be scarcely visible. In the beginning of April, 1671, it was again seen, an was rather brighter than at first. After several changes, it disappeared in March, 1672 and has not been observed since.

These remarkable facts seem to indicate, that there is a brilliant planetary system in this constellation, which, in some of its revolutions, becomes visible to us.

HISTORY.

Mythologists give various accounts of the origin of this constellation. Some suppose it is Orpheus, the celebrated musician, who, on being murdered by the cruel priestess of Bacchus, was changed into a Swan, and placed near his Harp in the heavens. Others suppose it is the swan into which Jupiter transformed himself when he deceived Leda, wife of Tyndarus, king of Sparta. Some affirm that it was Cycnus, a son of Neptune, who was so completely invulnerable that neither the javelins nor arrows, nor even the blows of Achilles, in furious combat, could make any impression.

"Headlong he leaps from off his lofty car,
And in close fight on foot renews the war;—
But on his flesh nor wound nor blood is seen,
The sword itself is blunted on the skin."

But when Achilles saw that his darts and blows had no effect on him, he immediately threw him on the ground and smothered him. While he was attempting to despoil him of his armor, he was suddenly changed into a swan.

"With eager haste he went to strip the dead;
The vanished body from his arms was fled.
His sea-god sire, to immortalize his fame,
Had turned it to a bird that bears his name."

According to Ovid, this constellation took its name from Cycnus, a relative of Phaeton, who deeply lamented the untimely fate of that youth, and the melancholy end of his sisters, who, standing around his tomb, wept themselves into poplars.

"Cycnus beheld the nymphs transformed, allied
To their dead brother on the mortal side,
In friendship and affection nearer bound;
He left the cities, and the realms he owned,
Through pathless fields, and lonely shores to range;
And woods made thicker by the sisters' change:
While here, within the dismal gloom alone,
The melancholy monarch made his moan;
His voice was lessened as he tried to speak,
And issued through a long-extended neck:
His hair transforms to down, his fingers meet
In skinny films, and shape his oary feet;
From both his sides the wings and feathers break;
And from his mouth proceeds a blunted beak;
All Cycnus now into a swan was turned."—*Ovid's Met.* b. ii.

HISTORY.—Various accounts? Story of Cycnus and Achilles? Ovid's account? Virgil's remarks respecting the Swan?

Virgil, also, in the 10th book of his Æneid, alludes to the same fable :—

"For Cycnus loved unhappy Phaeton,
And sung his loss in poplar groves alone
Beneath the sister shades to soothe his grief;
Heaven heard his song, and hasten'd his relief
And changed to snowy plumes his hoary hair,
And wing'd his flight to sing aloft in air."

Of all the feathered race, there is no bird, perhaps, which makes so beautiful and majestic an appearance as the swan. Almost every poet of eminence has taken notice of it. The swan has, probably, in all ages, and in every country where taste and elegance have been cultivated, been considered as the emblem of poetical dignity, purity, and ease. By the ancients it was consecrated to Apollo and the Muses; they also entertained a notion that this bird foretold its own end, and sang more sweetly at the approach of death.

———"She, like the swan
Expiring, dies in melody."—*Æschylus.*

"So on the silver stream, when death is nigh,
The mournful swan sings its own elegy."—*Ovid's Tristia.*

TELESCOPIC OBJECTS.

1. α Cygni (*Deneb*)—A bright star on the back of the Swan, with a telescopic companion; R. A. 20h. 35m. 57s.; Dec. N. 44° 42′ 07″. A 1, brilliant white; B 12½, pale blue.

2. β Cygni (*Albireo*)—A bright DOUBLE STAR on the bill of the figure; R. A. 19h. 24m. 16s.; Dec. N. 27° 37′ 07″. About 13½° south-southeast of Vega. A 3, topaz yellow; B 7, sapphire blue; the colors in brilliant contrast. A fine object, and the first double star ever seen by the present editor.

3. δ Cygni—A most delicate DOUBLE STAR in the middle of the left wing, 14° west of α Cygni; R. A. 19h. 39m. 58s.; Dec. N. 44° 44′ 06″. A 3½, pale yellow; B 9, sea green. Another beautiful object.

4. ζ Cygni—A star with a distant companion, on the tip of the right wing; R. A. 21h. 06m. 07s.; Dec. N. 29° 34′ 05″. A 3, pale yellow; B 10, sky blue; the field rich in small stars.

5. λ Cygni—A close DOUBLE STAR in the right or lower wing, with a distant companion; R. A. 20h. 41m. 11s.; Dec. N. 35° 54′ 03″. A 5, B 10, and C 6, all bluish.

6. μ Cygni—A beautiful DOUBLE STAR, with a distant companion, on the very tip of the right wing; R. A. 21h. 36m. 59s.; Dec. N. 28° 01′ 04″. A 5, white; B 6, and C 7½, both blue.

7. A BINARY STAR (61 Cygni)—the most remarkable known in the heavens. It is situated on the inner tip of the right wing of Cygni, 7½° south-by-east of Deneb, and nearly east of Vega; R. A. 20h. 59m. 43s.; Dec. N. 37° 58′ 0″. A 5½, and B 6, both yellow, but the latter of the deepest tint. From the great rapidity of its proper motion, this star is regarded as one of the nearest to our system. It affords a positive instance of a double star which, besides the individuals revolving round each other, or about their common center of gravity, has a progressive uniform motion towards some determinate region. It is supposed to be not less than 412,000 times the diameter of the earth's orbit from us; or 38,190,000,000,000 miles distant; and to be moving through space 60,000 times as fast as Mercury—the swiftest body known to our system. The period of 61 Cygni as a binary system, is about 450 years. For orbit, &c., see Map VIII., Fig. 18, and 19.

8. A fine DOUBLE STAR on the tip of the left wing, 10° northwest of α Cygni, and within 1° of θ; R. A. 19h. 37m. 34s.; Dec. N. 50° 09′ 3″. A 6½ and B 7, both pale fawn color.

9. A WIDE QUADRUPLE STAR in a rich field, on the Swan's left thigh, about 8° west by north of Deneb; R. A. 20h. 08m. 36s.; Dec. N. 46° 15′ 6″. A 4, orange; B 16, livid; C 7½, and D 5½, both cerulean blue. Not the effect of contrast.

10. A NEAT SMALL CLUSTER in the root of the neck, about 2° south of γ; R. A. 20h. 18m. 17s.; Dec. N. 37° 59′ 9″. A 8, yellow; B 11, dusky.

11. A LOOSE SPLASHY CLUSTER in a rich vicinity, between the Swan's tail and the Lizard, due south of β Cephei, and east-northeast of Deneb; R. A. 21h. 26m. 29s.; Dec. N. 47° 43′ 8″.

TELESCOPIC OBJECTS.—Alpha? Beta? Delta? Zeta? Lambda? Mu? What celebrated binary star? Remarks respecting? Period? Point out on the map. What other double star? Quadruple? What clusters? Nebula?

12. A VERY SINGULAR NEBULA on the tip of the northern wing, about 5½° north of δ; R. A. 19h. 40m. 35s.; Dec. N. 50° 07′ 6″. Seen to be nebulous only with good instruments. Several telescopic stars in the field. The Herschels considered this as a connecting link between planetary nebula and nebulous stars.

CAPRICORNUS (THE GOAT).—MAP V.

229. This is the tenth sign, and eleventh constellation, in the order of the Zodiac, and is situated south of the Dolphin, and next east of Sagittarius. Its mean declination is 20° south, and its mean right ascension 310°. It is therefore on the meridian about the 18th of September. It is to be observed that the first point of the *sign* Capricorn, *not the constellation*, marks the southern tropic, or winter solstice. The sun, therefore, arrives at this point of its orbit the 21st of December, but does not reach the *constellation* Capricorn until the 16th of January.

The sun, having now attained its utmost declination south, after remaining a few days apparently stationary, begins once more to retrace its progress northwardly, affording to the wintry latitudes of the north a grateful presage of returning spring.

At the period of the winter solstice, the sun is vertical to the tropic of Capricorn, and the southern hemisphere enjoys the same light and heat which the northern hemisphere enjoys on the 21st of June, when the sun is vertical to the tropic of Cancer. It is, at this period, mid-day at the south pole, and midnight at the north pole.

230. The whole number of stars in this constellation is fifty-one; none of which are very conspicuous. The three largest are only of the 3d magnitude. There is an equal number of the 4th.

The head of Capricorn may be recognized by means of two stars of the 3d magnitude, situated a little more than 2° apart, called *Giedi* and *Dabih*. They are 28° from the Dolphin, in a southerly direction.

Giedi is the most northern star of the two, and is double. If a line be drawn from Lyra through Altair, and produced about 23° farther, it will point out the head of Capricorn. These two stars come to the meridian the 9th of September, a few minutes after Sad'r, in Cygnus. A few other stars of inferior note may be traced out by reference to the maps.

The *sign* of the Goat was called by the ancient orientalists the "Southern gate of the Sun," as Cancer was denominated the "Northern gate." The ten stars in the *sign* Capricorn, known to the ancients by the name of the "Tower of Gad," are probably now in the constellation Aquarius.

HISTORY.

Capricornus is said to be Pan, or Bacchus, who, with some other deities, were feasting near the banks of the Nile, when suddenly the dreadful giant Typhon came upon them, and compelled them all to assume a different shape, in order to escape his fury. Ovid relates,

"How Typhon, from the conquer'd skies, pursued
Their routed godheads to the seven-mouth'd flood:

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229. Position of Capricornus? When does the sun enter it? What said of his place and motion at that time? Of the winter solstice? 230. Number of stars in Capricorn? Their magnitudes? How recognize the figure? What said of Giedi? Ancient name of this sign?

Forced every god (his fury to escape),
Some beastly form to take, or earthly shape.
Jove (sings the bard) was changed into a ram,
From whence the horns of Libyan Ammon came;
Bacchus a goat; Apollo was a crow;
Phœbe a cat; the wife of Jove a cow,
Whose hue was whiter than the falling snow;
Mercury to a nasty ibis turned—
While Venus from a fish protection craves,
And once more plunges in her native waves."

On this occasion it is further related that Bacchus, or Pan, led the way and plunged into the Nile, and that the part of his body which was under the water assumed the form of a fish, and the other part that of a goat; and that to preserve the memory of this frolic, Jupiter made him into a constellation, in his metamorphosed shape.

Some say that this constellation was the goat Amalthea, who supported the infan Jupiter with her milk. To reward her kindness, the father of the gods placed her among the constellations, and gave one of her horns to the nymphs who had taken care of him in his infantile years. This gift was ever after called the *horn of plenty;* as it possessed the virtue of imparting to the holder whatever she desired. On this account the Latin term *Cornucopia*, denotes plenty, or abundance of good things. The word Amalthea, when used figuratively, has also the same meaning.

The real sense of this fable, divested of poetical embellishment, appears to be this; that in Crete, some say in Libya, there was a small territory shaped very much like a bullock's horn, and exceedingly fertile, which the king presented to his daughter Amalthea, whom the poets feigned to have been Jupiter's nurse.

"The bounteous Pan," as he is styled by Milton, was the god of rural scenery, shepherds, and huntsmen. Virgil thus addresses him :—

"And thou, the shepherd's tutelary god,
Leave, for a while, O Pan! thy loved abode."

The name of Pan is derived from a Greek word signifying *all things;* and he was often considered as the great principle of vegetable and animal life. He resided chiefly in Arcadia, in woods and the most rugged mountains. As Pan usually terrified the inhabitants of the adjacent country, even when he was nowhere to be seen, that kind of fear which often seizes men, and which is only ideal or imaginary, has received from him the name of *Panic.*

Pales, the female deity corresponding to Pan, was the goddess of sheepfolds and of pastures among the Romans. Thus Virgil :—

" Now, sacred Pales, in a lofty strain,
I sing the rural honors of thy reign."

The shepherds offered to this goddess milk and honey, to gain her protection over their flocks. She is represented as an old woman, and was worshiped with great solemnity at Rome. Her festivals, which were called *Pulilia*, were celebrated on the 20th of April, the day on which Romulus laid the foundations of the city.

TELESCOPIC OBJECTS.

1. α Capricorni—A quintuple star in the right horn ; R. A. 20h. 09m. 10s.; Dec. S. 13° 02′ 1″. A 3, pale yellow; B (or α 1) 4, yellow; C 16, blue; D 9, ash-colored; E 9½, lilac tinge. Few telescopes will reveal all these components.

2. β Capricorni—A wide pair of stars in the right horn, 2½° south-half-east of α; R. A. 20h. 12m. 01s.; Dec. S. 15° 16′ 9″. A 3½, orange yellow; B 7, sky blue. Other small stars in the field. It requires, a powerful instrument, and the most favorable circumstances to detect the minute star 5. (See Map VIII., Fig. 20.)

3. A globular cluster between Aquarius and the neck of Capricorn, 9° due east of α Capricorni, about ½° from a 6th magnitude star; R. A. 20h. 44m. 39s.; Dec. S. 13° 07′ 6″. Many stars in the field, two of which are close to the cluster, or the east. Map IX., Fig. 63.

History.—Who was Capricornus? What proof cited? What further? What other myth? Meaning of this fable? What said of Pales?

Telescopic Objects.—Alpha? Beta? Point out on the map? What clusters? Where shown on the map?

4. A fine PALE WHITE CLUSTER, about 20° west-northwest of Fomalhaut; R. A. 21h. 31m. 16s.; Dec. S. 23° 52′ 4″. A bright object, with straggling streams of stars, and but few outliers in the field. Seen with small instruments. Map IX., Fig. 64.

CHAPTER XII.

CONSTELLATIONS ON THE MERIDIAN IN OCTOBER.

PEGASUS (THE FLYING HORSE).—MAP II.

231. THIS constellation is represented in an inverted posture, with wings. It occupies a large space in the heavens, between the Swan, the Dolphin and the Eagle, on the west, and the Northern Fish and Andromeda, on the east. Its mean right ascension is 340°, or it is situated 20° W. of the *prime meridian.* It extends from the equinoctial N. 35°. Its mean length E. and W. is about 40°, and it is six weeks in passing our meridian, viz., from the 1st of October to the 10th of November.

232. We see but a part of Pegasus, the rest of the animal being, as the poets imagined, hid in the clouds. It is readily distinguished from all other constellations by means of four remarkable stars, about 15° apart, forming the figure of a square called the *Square of Pegasus.*

The two western stars in this square come to the meridian about the 23d of October, and are 13° apart. The northern one, which is the brightest of three triangular stars in the martingale, is of the 2d magnitude, and is called *Scheat.* Its declination is 26¾°. *Markab*, also, of the 2d magnitude, situated in the head of the wing, is 13° S. of Scheat, and passes the meridian 11 minutes after it.

The two stars which form the eastern side of the square, come to the meridian about an hour after those in the western. The northern one has already been described as *Alpheratz* in the head of Andromeda, but it also belongs to this constellation, and is 14° E. Scheat. 14° S. of Alpheratz, is *Algenib*, the last star in the wing, situated 16½° E. of Markab.

233. *Algenib* in *Pegasus, Alpheratz* in Andromeda, and *Caph* in Cassiopeia are situated on the *prime meridian*, and point out its direction through the pole. For this reason they are sometimes called the *three guides.* They form an arc of that great circle in the heavens from which the distances of all the heavenly bodies are measured.

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231. What constellations in this chapter? Describe Pegasus, its size, position, &c. 232. Do we see the whole of the figure? How is it distinguished? What said of Scheat and Markab? Of Alpheratz and Algenib? 233. Remark respecting Algenib, Alpheratz and Caph? What sometimes called, and why? They form what? Remarks

It is an arc of the equinoctial colure which passes through the vernal equinox, and which the sun crosses about the 21st of March. It is, in astronomy, what the meridian of Greenwich is in geography. If the sun, or a planet, or a star, be said to have so many degrees of right ascension, it means that the sun or planet has *ascended* so many degrees from this prime meridian.

Enif, sometimes called *Enir*, is a star of the 3d magnitude in the nose of Pegasus, about 20° W. S. W. of Markab, and half-way between it and the Dolphin. About half of the distance from Markab toward Enif, but a little to the S., there is a star of the 3d magnitude situated in the neck, whose *letter* name is *Zeta*. The loose cluster directly S. of the line joining Enif and Zeta, forms the head of Pegasus.

In this constellation there are eighty-nine stars visible to the naked eye, of which three are of the second magnitude and three of the third.

HISTORY.

This, according to fable, is the celebrated horse which sprung from the blood of Medusa, after Perseus had cut off her head. He received his name according to Hesiod, from his being born near the sources (πηγη, Pege) of the ocean. According to Ovid, he fixed his residence on Mount Helicon, where, by striking the earth with his foot, he raised the fabled fountain called Hippocrene. He became the favorite of the Muses; and being tamed by Neptune or Minerva, he was given to Bellerophon, son of Glaucus, king of Ephyre, to aid him in conquering the Chimæra, a hideous monster that continually vomited flames. This monster had three heads, that of a lion, a goat, and a dragon. The fore parts of its body were those of a lion, the middle those of a goat, and the hinder those of the dragon. It lived in Lycia, of which the top, on account of its desolate wilderness, was the resort of lions, the middle, which was fruitful, was covered with goats, and at the bottom, the marshy ground abounded with serpents. Bellerophon was the first who made his habitation upon it.

Plutarch thinks the Chimæra was the captain of some pirate who adorned their ship with the images of a lion, a goat, and a dragon.

After the destruction of this monster, Bellerophon attempted to fly up to heaven upon Pegasus; but Jupiter was so displeased at this presumption, that he sent an insect to sting the horse, which occasioned the melancholy fall of his rider. Bellerophon fell to the earth, and Pegasus continued his flight up to heaven, and was placed by Jupiter among the constellations.

> " Now heav'n his further wand'ring flight confines,
> Where, splendid with his num'rous stars, he shines."
>
> *Ovid's Fasti.*

TELESCOPIC OBJECTS.

1. *α* Pegasi (*Markab*)—A star with a distant companion, at the junction of the wing and shoulder, 13° south of Scheat; R. A. 22h. 56m. 47s.; Dec. N. 14° 20′ 08″. A 2, white; B 11, pale grey.

2. *β* Pegasi (*Scheat*)—A bright star with a minute distant companion, on the left foreleg; R. A. 22h. 56m. 01s.; Dec. N. 27° 13′ 0″. A 2, deep yellow; B 15, blue; with two other stars in the field.

3. *γ* Pegasi (*Algenib*)—A star with a distant companion, on the edge of the wing; R. A. 0h. 05m. 0s.; Dec. N. 14° 17′ 07″. A 2½, yellow; B 13, pale blue.

4. *ε* Pegasi (*Enif*)—A star with two distant companions, in the nose of the figure; R. A. 21h. 36m. 19s.; Dec. N. 9° 08′ 07″. A 2½, yellow; B 14, blue; C 9, violet; and a 9th magnitude star of a violet tinge, at a distance east.

5. *ζ* Pegasi—A star with a minute companion in the middle of the neck; R. A. 22h. 33m. 29s.; Dec. N. 9° 59′ 9″. A line from Alpheratz over Markab, and carried 7° further, will reach *ζ*. A 3, light yellow; B 13, dusky; with other stars in the field.

6. A double star between the head of Pegasus and the hind legs of the Fox; or about 10½° south by east of *ζ* Cygni; R. A. 21h. 14m. 41s.; Dec. N. 19° 07′ 4″. A 4, pale orange, and considered variable; B 9, purplish.

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respecting the prime meridian? What said of Enif? Of Zeta? Of the *head* of Pegasus Number of stars in the constellation, and their magnitudes?

History.—Story of his origin and name? Residence, &c.? How he came among the stars?

Telescopic Objects.—Alpha? Beta? Gamma? Epsilon? Zeta? What double star? What cluster? Point out on the map. What nebula?

7. A GLOBULAR CLUSTER between the mouths of Pegasus and Eqüleus, about 4° northwest of ε; R. A. 21h. 22m. 13s.; Dec. N. 11° 27′ 4″. Map IX., Fig. 65. It is laid down as a nebula on Map II., but with a good instrument it is resolved into stars, with straggling outliers, as shown in the diagram.

8. An ELONGATED NEBULA in the animal's mane, about 3° due south of Markab; R. A. 22h. 56m. 58s.; Dec. N. 11° 27′ 9″. A very faint and difficult object.

EQULEUS, VEL EQUI SECTIO (THE LITTLE HORSE, OR THE HORSE'S HEAD).—MAP II.

234. This Asterism, or small cluster of stars, is situated about 7° W. of Enif, in the head of Pegasus, and about half-way between it and the Dolphin. It is on the meridian at 8 o'clock, on the 11th of October. It contains ten stars, of which the four principal are only of the 4th magnitude. These may be readily distinguished by means of the long irregular square which they form. The two in the nose are much nearer together than the two in the eyes: the former being 1° apart, and the latter 2½°. Those in the nose are uppermost, being 4° N. of those in the eyes. This figure also is in an *inverted* position. These four stars are situated 10° or 12° S. E. of the diamond in the Dolphin's head. Both of these clusters are noticeable on account of their figure rather than their brilliancy.

HISTORY.

This constellation is supposed to be the brother of Pegasus, named *Celeris*, given by Mercury to Castor, who was so celebrated for his skill in the management of horses; others take him to be the celebrated horse which Neptune struck out of the earth with his trident, when he disputed with Minerva for superiority. The head only of Celeris is visible, and this, also, is represented in an inverted position.

TELESCOPIC OBJECTS.

Four of the principal stars in this little group are double—namely, β, δ, ε and λ. β is rather a star with a companion; R. A. 21h. 14m. 57s.; Dec. N. 6° 07′ 9″. The other three will easily be found from their proximity to β.

AQUARIUS (THE WATER-BEARER).—MAP II.

235. This constellation is represented by the figure of a man pouring out water from an urn. It is situated in the Zodiac, immediately S. of the equinoctial, and bounded by the Little

234. Situation of Eqüleus? When on the meridian? Number of stars, and how distinguished? What further description?
HISTORY.—What suppositions respecting the origin of Eqüleus?
TELESCOPIC OBJECTS.—What double stars? How found?
235. How is Aquarius represented? Its boundaries?

Horse, Pegasus, and the Western Fish on the N., the Whale on the E., the Southern Fish on the S. and the Goat on the W.

236. Aquarius is now the 12th in order, or last of the Zodiacal constellations ; and is the name of the 11th *sign* in the ecliptic. Its mean declination is 14° S., and its mean right ascension 335°, or 22 hours, 20 min. ; it being 1 hour and 40 min. W. of the equinoctial colure ; its center is, therefore, on the meridian the 15th of October.

It contains one hundred and eight stars ; of which the four largest are all of the 3d magnitude.

> "His head, his shoulders, and his lucid breast,
> Glisten with stars ; and where his urn inclines,
> Rivers of light brighten the watery track."

237. The northeastern limit of Aquarius may be readily distinguished by means of four stars of the 4th magnitude, in the hand and handle of the urn, so placed as to form the letter Y, very plainly to be seen, 15° S. E. of *Enif*, or 18° S. S. W. of Markab, in Pegasus ; making with the two latter nearly a right angle.

About 4½° W. of the figure is *El Melik*, a star of the 3d magnitude, in the E. shoulder, and the principal one in this constellation. 10° S. W. of El Melik, is another star of the same magnitude, situated in the W. shoulder, called *Sad es Saud*.

Ancha, of the 4th magnitude, is in the right side, 8° S. of El Melik. 9° E. of Ancha, is another star of the 4th magnitude, whose letter name is *Lambda*.

Scheat, of the 3d magnitude, lying below the knee, is situated 8½° S. of Lambda ; and 14° S. of Scheat, the brilliant star Fomalhaut, of between the 1st and 2d magnitudes, terminates the cascade in the mouth of the Southern Fish. This star is common to both these constellations, and is one of those from which the lunar distance is computed for ascertaining the longitude at sea. It culminates at 9 o'clock on the 22d of October.

Fomalhaut, Deneb Kaitos, and Alpha in the head of the Phœnix, make a large triangle, whose vertex is in Deneb Kaitos. Those two stars of the fourth magnitude, situated 4° S. of Sad es Saud, and nearly the same distance from Ancha, are in the tail of Capricorn. They are about 2° apart. The western one is called *Deneb Algedi*.

The rest of the stars in the cascade are quite small; they may be traced from the letter Y, in the urn, in a southeasterly direction toward the tail of Cetus, from which the cascade suddenly bends off near Scheat, in an opposite course, and finally disappears in the mouth of the Southern Fish, 30° S. of Y.

HISTORY.

This constellation is the famous Ganymede, a beautiful youth of Phrygia, son of Tros, king of Troy, or, according to Lucian, son of Dardanus. He was taken up to heaven by Jupiter as he was tending his father's flocks on Mount Ida, and became the cup-bearer of the gods in place of Hebe. There are various opinions, however, among the ancients respecting its origin. Some suppose it represents Deucalion, who was placed among the stars after the celebrated deluge of Thessaly, 1500 years before the birth of our Saviour ; while others think it designed to commemorate Cecrops, who came from Egypt to Greece, founded Athens, established science, and introduced the arts of polished life.

The ancient Egyptians supposed the setting or disappearance of Aquarius caused the Nile to rise, by the sinking of his urn in the water. In the Zodiac of the Hebrews, Aquarius represents the tribe of Reuben.

Its order in the signs and constellations? Number and size of its stars? 237. How distinguish the northeast limit? What said of El Melik? Of Sad es Saud? Of Ancha, Lambda, Scheat, &c.

HISTORY.—Story of Ganymede, and Jupiter? What other myth? Idea of the Egyptains? Hebrew Zodiac?

TELESCOPIC OBJECTS.

1. α Aquarii (*Phard*)—A star with a minute companion on the Water-bearer's left shoulder; R. A. 21h. 57m. 33s.; Dec. S. 1° 05′ 07″. A 3, pale yellow; B 13, grey; and another star in the field on a line with A and B. Markab is on a line joining Alpheratz and Phard, and about half way between them.

2. β Aquarii (*Sad-al-melik*)—A star with a companion on the right shoulder; R. A. 21h. 23m. 07s.; Dec. N. 6° 16′ 04″. A 3, pale yellow; B 15, blue. A very delicate object.

3. γ Aquarii—A delicate but wide double star, on the water-pot; R. A. 22h. 13m. 23s.; Dec. S. 2° 11′ 05″. A 4, greenish tinge; B 14, purple. It is about 4° east-by-south from Sad-al-melik.

4. ζ Aquarii—A binary star in the left wrist, about 6° east from Sadalmelik; R. A. 22h. 20m. 35s.; Dec. S. 0° 50′ 02″. A 4, very white; B 4½, white.

5. τ' Aquarii—A fine double star in the left leg, one third of the way from Fomalhaut to ζ Pegasi; R. A. 22h. 39m. 13s.; Dec. S. 14° 53′ 09″. A 6, white; B 9½, pale garnet.

6. ψ' Aquarii—A double star in the stream, being the first of three similar stars marked ψ^1, ψ^2, ψ^3; R. A. 23h. 07m. 30s.; Dec. S. 9° 57′ 05″. A 5½, orange tint; B 9, sky blue. It is about one-third of the way from Fomalhaut to α Andromedæ. Several other beautiful double stars east of Scheat, in the stream, as shown on the map.

7. A fine globular cluster near the neck of Aquarius, about 5° north-half-east from β; R. A. 21h. 23m. 07s.; Dec. S. 6° 16′ 04″. A cluster of exceedingly small stars, which has been likened to "a heap of fine sand." Several telescopic outliers in the field. Map VIII., Fig. 66.

8. A planetary nebula in the middle of the scarf; R. A. 20h. 55m. 27s.; Dec. S. 11° 59′ 03″. About 12° east of α Capricorni, where a line from the Eagle's tail over θ Antinoi, and as far again, reaches it. It is bright to its very disc, and but for its pale blue tint, would be a very miniature of Venus.

PISCES AUSTRALIS (the southern fish).—MAP II.

238. This constellation is directly S. of Aquarius, and is represented as a fish drinking the water which Aquarius pours from his urn. Its mean declination is 31° S. and its mean right ascension and time of passing the meridian are the same as those of Aquarius, and it is seen on the meridian at the same time, viz. on the 15th of October. It contains 24 visible stars, of which one is of the 1st magnitude, or between the 1st and 2d, two are of the 3d, and five of the 4th. The first and most beautiful of all is *Fomalhaut*, situated in the mouth. This is 14° directly S. of Scheat in Aquarius, and may be seen passing the meridian low down in the southern hemisphere, on the 22d and 23d of October. Its position in the heavens has been determined with the greatest possible accuracy, to enable navigators to find their longitude at sea.

The mode of doing this cannot be explained here. The problem is one of some difficulty. It consists in finding the angular distance between some star whose position is well known,

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Telescopic Objects.—Alpha? Beta? Gamma? Zeta? Tau? Psi? What clusters, and where shown on the map? What nebula?

238. Situation of Pisces Australis? How represented? When on the meridian? Number of stars? Magnitude? The principal star? How situated? What use made of it? What said of the method of finding the longitude by the moon and stars?

and the moon when she is passing near it; also, the altitude of each, at the same instant, with good sextants. These data furnish the elements of a spherical triangle, the solution of which, after various intricate corrections, is made to result in the longitude of the given place.—*See note to Arietes.* In 1714, the British Parliament offered a reward of 10,000 pounds sterling, to any man who should discover a method of determining the longitude within 1°, or 60 geographical miles of the truth; 15,000 pounds to the man who should find it within 40 miles, and 20,000 pounds, if found within 30 miles. These rewards in part, have been since distributed among eminent mathematicians, in Europe, agreeably to the respective merits of their discoveries.

HISTORY.

This constellation is supposed to have taken its name from the transformation of Venus into the shape of a fish, when she fled, terrified at the horrible advances of the monster Typhon, as we have related in the mythology of the Fishes.—(*See Pisces.*)

TELESCOPIC OBJECTS.

α PISCES AUSTRALIS—A first magnitude star with a very distant companion, in the eye of the fish; R. A. 22h. 48m. 48s.; Dec. S. 30° 28′ 03″. A 1, reddish; B 9½, dusky blue.

LACERTA (THE LIZARD).—MAP II.

239. This is a small and obscure modern constellation, between the tail of Cygnus and the head of Andromeda. It has one star of the 4th magnitude, eight of the 5th, and a few much smaller.

240. Between Lacerta and Andromeda a singular looking figure appears on the map, called *Gloria Frederica;* or *Frederic's Glory.* It was inserted among the constellations by Bode, in 1787, as a compliment to Frederic II., of Prussia. It consists of a *crown*, a *laurel*, a *sword*, and a *pen*, to represent the monarch, the hero, the sage, and the pacificator. But the constellation was not recognized by astronomers, and, as such, has already passed from the heavens.

TELESCOPIC OBJECTS.

1. A neat DOUBLE STAR on the tip of the Lizard's tail; R. A. 22h. 11m. 56s.; Dec. N. 36° 58′ 01″. A 6½, pale white; B 9, livid.

2. A delicate but wide DOUBLE STAR on the shoulder; R. A. 22h. 14m. 25s.; Dec. N. 45° 43′ 09″. A 5, pale yellow; B 13, orange tint. A line from Polaris carried by the east of Cepheus tiara, and 11° further, will find it the lucida of a fine galaxy field.

3. A WIDE DOUBLE STAR near the end of the tail, the southern star of three forming a neat triangle; R. A. 22h. 32m. 05s.; Dec. N. 38° 13′ 2″. A 6½, white; B 10, violet.

4. A DELICATE TRIPLE STAR in the space between the Lizard's back and the left hand of Andromeda; R. A. 22h. 49m. 06s.; Dec. N. 40° 45′ 1″. A 6, bright white; B. 15, pale blue; C 9½, reddish; a fourth star at a distance. A very difficult object; claimed by some for Andromeda, but usually classed as belonging to the Lizard.

HISTORY.—Supposed origin of this constellation?
TELESCOPIC OBJECTS.—Alpha? Where situated?
239. Describe Lacerta. Where situated? 240. What other small constellation near? By whom inserted, when and why? Of what does it consist? To represent what? Is it recognized by astronomers?
TELESCOPIC OBJECTS.—What double stars in Lacerta? What triple star? Quadruple? Cluster? Any of them shown on the map?

5. A QUADRUPLE STAR, the western one of the three forming the triangle at the end of the tail; R. A. 22h. 29m. 46s.; Dec. N. 38° 48′ 5″. About 20° northwest of Alpheratz. A and B 6½, both white; C 11, greenish; D 10, blue.

6. A LARGE LOOSE CLUSTER in the Lizard's mouth; R. A. 22h. 08m. 59s.; Dec. N. 49° 05 1″. Stars from the 9th to the 14th magnitudes. A line carried from Polaris through the tiara of Cepheus, and 8° beyond, strikes it.

CHAPTER XIII.

VARIABLE AND DOUBLE STARS—CLUSTERS AND NEBULÆ.

241. THE periodical variations of brilliancy to which some of the fixed stars are subject, may be reckoned among the most remarkable of their phenomena. Several stars, formerly distinguished by their splendor, have entirely disappeared; others are now conspicuous which do not seem to have been visible to the ancient observers; and there are some which alternately appear and disappear, or, at least, of which the light undergoes great periodic changes. Some seem to become gradually more obscure, as *Delta* in the Great Bear; others, like *Beta* in the Whale, to be increasing in brilliancy.

242. Some stars have all at once blazed forth with great splendor, and, after a gradual diminution of their light, again become extinct. The most remarkable instance of this kind is that of the star which appeared in 1572, in the time of Tycho Brahe. It suddenly shone forth in the constellation Cassiopeia, with a splendor exceeding that of stars of the first magnitude, even of Jupiter and of Venus, at their least distances from the earth; and could be seen with the naked eye, on the meridian, in full day! Its brilliancy gradually diminished from the time of its first appearance, and at the end of sixteen months it entirely disappeared, and has never been seen since. *(See a more particular account of this phenomenon, page 35.)*

Another instance of the same kind was observed in 1604, when a star of the first magnitude suddenly appeared in the right foot of Ophiuchus. It presented, like the former, all the phenomena of a prodigious flame, being, at first, of a dazzling white, then of a reddish yellow, and, lastly, of a leaden paleness; in which its light expired. These instances prove that the stars are subject to great physical revolutions. (*Page* 90)

243. A great number of stars have been observed whose light seems to undergo a regular periodic increase and diminution.

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241. What said of the periodical variations of the stars? 242. What other remarkable phenomenon? What instances cited? What do these instances prove? 243. What

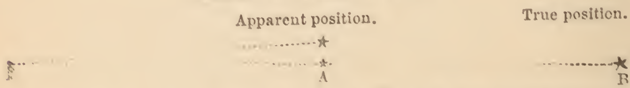
They are properly called *Variable Stars*. One in the *Whale* has a period of 344 days and is remarkable for the *magnitude* of its variations. From being a star of the second magnitude, it becomes so dim as to be seen with difficulty through powerful telescopes. Some are remarkable for the *shortness of the period* of their variation. *Algol* has a period of between two and three days; *Delta Cephei*, of 5⅓ days; *Beta Lyræ*, of 6 2-5 days; and *Mu Antinoi*, of 7 days.

The regular succession of these variations precludes the supposition of an actual destruction of the stars; neither can the variations be supposed to arise from a change of distance; for, as the stars invariably retain their apparent places, it would be necessary to suppose that they approach to, and recede from the earth in *straight lines*, which is very improbable. The most probable supposition is, that the stars revolve, like the sun and planets, about an axis. "Such a motion," says the elder Herschel, "may be as evidently proved, as the diurnal motion of the earth. Dark spots, or large portions of the surface, less luminous than the rest, turned alternately in certain directions, either toward or from us, will account for all the phenomena of periodical changes in the luster of the stars, so satisfactorily, that we certainly need not look for any other cause."

DOUBLE STARS.

244. On examining the stars with telescopes of considerable power, many of them are found to be composed of two or more stars, placed contiguous to each other, or of which the distance subtends a very minute angle. This appearance is, probably, in many cases, owing solely to the optical effect of their position relative to the spectator; for it is evident that two stars will appear contiguous if they are placed nearly in the same line of vision, although their real distance may be immeasurably great.

STARS OPTICALLY DOUBLE.



Here the observer on the left sees a large and small star at A, apparently near together—the lowest star being much the smallest. But instead of their being situated as they appear to be, with respect to each other, the true position of the smaller star may be at B instead of A; and the difference in their apparent magnitudes may be wholly owing to the greater distance of the lower star.

Upon this subject Dr. Herschel remarks, that this nearness of the stars to each other, in certain cases, might be attributed to some accidental cause, did it occur only in a few instances; but the frequency of this companionship, the extreme closeness, and, in many cases, the near equality of the stars so conjoined, would alone lead to a strong suspicion of a more near and intimate relation than mere casual juxtaposition.

245. There are, however, many instances in which the angle of position of the two stars varies in such a manner as to indi-

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are these unsteady stars called? What specimens referred to, and their periods? What does this regular succession, &c., prove? What theory did Dr. Herschel adopt respecting the variable stars? 244. What said of double stars? Are they always really near each other? Illustrate on blackboard. Remark of Dr. Herschel? 245. Are they cate a revolution about each other and about a *common center*. In this case they are said to form a *Binary system* performing to each other the office of sun and planet, and are connected together by laws of gravitation like those which prevail in the solar system.

The recent observations of Sir John Herschel and Sir James South, have established the truth of this singular fact beyond a doubt. Motions have been detected, so rapid as to become measurable within very short periods of time; and at certain epochs, the satellite or feebler star has been observed to disappear, either passing behind or before the primary, or approaching so near to it that its light has been absorbed by that of the other.

246. The most remarkable instance of a regular revolution of this sort, is that of *Mizar*, in the tail of the Great Bear; in which the angular motion is 6 degrees and 24 minutes of a great circle, annually; so that the two stars complete a revolution about one another in the space of 58¼ years. About eleven-twelfths of a complete circuit have been already described since its discovery in 1781, the same year in which the planet Herschel was discovered.

A double star in Ophiuchus presents a similar phenomenon, and the satellite has a motion in its orbit still more rapid. *Castor* in the Twins, *Gamma Virginis*, *Zeta* in the Crab, *Zi Bootis*, *Delta Serpentis*, and that remarkable double star 61 *Cygni*, together with several others, amounting to 40 in number, exhibit the same evidence of a revolution about each other and about a common center. (For a more particular description of these stars, see Telescopic Objects and the Map.)

But it is to be remembered that these are not the revolutions of bodies of a planetary nature around a solar center, but of sun around sun—each, perhaps, accompanied by its train of planets, and *their* satellites, closely shrouded from our view by the splendor of their respective suns, and crowded into a space bearing hardly a greater proportion to the enormous interval which separates *them*, than the distances of the satellites of our planets from their primaries bear to their distances from the sun itself.

247. The examination of double stars was first undertaken by the late Sir William Herschel, with a view to the question of parallax. His attention was, however, soon arrested by the new and unexpected phenomena which these bodies presented.

Sir William observed of them, in all, 2400. Sir James South and Herschel have given a catalogue of 380 in the Transactions of the Royal Society for 1824, and South added 458 in 1826. Sir John Herschel, in addition to the above, published an account of 1000, before he left England for the Cape of Good Hope, where he went to push his discoveries in the southern hemisphere. Professor Struve, with the great Dorpat telescope, has given a catalogue of 3,063 of the most remarkable of these stars.

The object of these catalogues is not merely to fix the place of the star within such limits as will enable us easily to discover it at any future time, but also to record a description

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ever really near each other? What motion? What do these constitute? Is it certain that stars are ever thus in motion around a common center? 246. What remarkable instance cited? Its annual angular motion? Period? What other binary systems? Are these *planetary* systems like our own? 247. Who first undertook the examination of the double stars, and with what view? What number did he observe? What cataof the appearance, position, and mutual distances of the individual stars composing the system, in order that subsequent observers may have the means of detecting their connected motions, or any changes which they may exhibit. Professor Struve has also taken notice of 52 triple stars, among which No. 11 of the *Unicorn*, *Zeta* of Cancer, and *Zi* of the Balance, appear to be *ternary systems* in motion. Quadruple and quintuple stars have likewise been observed, which also appear to revolve about a common center of gravity; in short, every region of the heavens furnishes examples of these curious phenomena.

COLOR OF THE STARS.

248. Many of the double stars exhibit the curious and beautiful phenomenon of *contrasted colors*, or *complimentary tints*. In such instances, the larger star is usually of a ruddy or orange hue, while the smaller one appears blue or green, probably in virtue of that general law of optics, which provides that when the retina is under the influence of excitement by any bright colored light, feebler lights, which, seen alone, would produce no sensation but that of whiteness, shall for the time appear colored with the tint complimentary to that of the brighter.

Thus, a yellow color predominating in the light of the brighter star, that of the less bright one, in the same field of view, will appear blue; while, if the tint of the brighter star verge to crimson, that of the other will exhibit a tendency to green—or even appear a vivid green. The former contrast is beautifully exhibited by *Iota*, in Cancer; the latter by *Almaack*, in Andromeda—both fine double stars. If, however, the colored star be much the less bright of the two, it will not materially affect the other. Thus, for instance, *Eta* Cassiopeiæ exhibits the beautiful combination of a large white star, and a small one of a rich ruddy purple.

249. It is not easy to conceive what variety of illumination *two suns*—a red and a green, or a yellow and a blue one—must afford to a planet revolving about either; and what charming contrasts and grateful vicissitudes—a *red* and a *green* day, for instance, alternating with a *white* one and with *darkness*—might arise from the presence or absence of one or the other, or both, above the horizon.

Insulated stars of a red color, almost as deep as that of blood, occur in many parts of the heavens, but no green or blue star (of any decided hue) has, we believe, ever been noticed, unassociated with a companion brighter than itself.

CLUSTERS OF STARS.

250. When we cast our eyes over the concave surface of the heavens in a clear night, we do not fail to observe that there are, here and there, groups of stars which seem to be compressed together more densely than those in the neighboring parts; forming bright patches or clusters.

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logues? Their object? What triple stars? Ternary systems? Quadruple stars, &c.? 248. What said of the *colors* of the stars? What law of optics referred to? What illustrations? 249. What remarks respecting red and green suns, &c.? Of insulated stars of a red color? 250. What said of clusters? What specimen referred to? Pleiades?

The *Pleiades* are an instance of this kind, in which six or seven stars may be seen in near proximity, by the naked eye; and even more if the eye be turned carelessly upon it; for it is a remarkable fact that the *center* of the eye is far less sensible to feeble impressions of light, than the exterior portion of the retina. Rheita affirms that by the aid of a telescope he counted over 200 stars in this small cluster. See Map VIII., Fig. 28.

In the constellation called *Coma Berenices* there is another group more diffused, and consisting of much larger stars. In Cancer there is a nebulous cluster of very minute stars, called *Præsepe*, or the Beehive, which is sufficiently luminous to be seen by the naked eye, in the absence of the moon, and which any ordinary spyglass will resolve into separate stars. In the sword-handle of Perseus, also, is another such spot, crowded with stars. It requires, however, rather a better telescope to resolve it into individual stars. See p. 65, and Map VIII., Fig. 39.

Whatever be the nature of these clusters, it is certain that other laws of aggregation prevail in them, than those which have determined the scattering of stars over the general surface of the sky. Many of them, indeed, are of an exactly round figure, and convey the idea of a globular space filled full of stars, and constituting, in itself, a family or society apart, and subject only to its own internal laws.

"It would be a vain task," says the younger Herschel, "to attempt to count the stars in one of these globular clusters. They are not to be reckoned by hundreds; for it would appear that many clusters of this description must contain, at least, ten or twenty thousand stars, compacted and wedged together in a round space, not more than a tenth part as large as that which is covered by the moon.

NEBULÆ.

251. The *Nebulæ*, so called from their dim, cloudy appearance, form another class of objects which furnish matter for curious speculation and conjecture respecting the formation and structure of the sidereal heavens. When examined with a telescope of moderate powers, the greater part of the nebulæ are distinctly perceived to be composed of little stars, imperceptible to the naked eye, because, on account of their apparent proximity, the rays of light proceeding from each are blended together, in such a manner as to produce only a confused luminous appearance.

In other nebulæ, however, no individual stars can be perceived, even through the best telescopes; and the nebulæ exhibit only the appearance of a self-luminous phosphorescent patch of gaseous vapor, though it is possible that even in this case, the appearance may be owing to a congeries of stars so minute, or so distant, as not to afford, singly, sufficient light to make an impression on the eye.

Remarks upon their nature and the laws that govern them? Remarks of Herschel? 251. What are *nebulæ*, and why so called? How appear through telescopes? Are they all resolvable into stars?

252. One of the most remarkable nebulæ is in the sword-handle of Orion. It is formed of little flocky masses, like wisps of cloud, which seem to adhere to many small stars at its outskirts. It is not very unlike the mottling of the sun's disc, but of a coarser grain, and with darker intervals. These wisps of light, however, present no appearance of being composed of small stars; but in the intervals between them, we fancy that we see stars, or that, could we strain our sight a little more, we should see them. These intervals may be compared to openings in the firmament, through which, as through a window, we seem to get a glimpse of other heavens, and brighter regions, beyond. See page 45, and Map VIII., Fig. 32.

253. Another very remarkable nebula is that in the girdle of Andromeda, which, on account of its being visible to the naked eye, has been known since the earliest ages of astronomy. It is often mistaken for a comet, by those unacquainted with the heavens. See page 20, and Map VIII., Fig. 22.

Marius, who noticed it in 1612, describes its appearance as that of a candle shining through horn; and the resemblance is certainly very striking. Its form is a long oval, increasing, by insensible gradations of brightness, from the circumference to a central point, which, though very much brighter than the rest, is not a star, but only a nebula in a high state of condensation. It occupies an area comparatively large—equal to that of the moon in quadrature. This nebula may be considered as a type, on a large scale, of a very numerous class of nebulæ, of a round or oval figure, increasing more or less in density toward the center.

254. *Annular nebulæ* are those in the form of a *ring*, but are among the rarest objects in the heavens. The most conspicuous of this class is to be found exactly half-way between the stars *Beta* and *Gamma* Lyræ, and may be seen with a telescope of moderate power. It is small, and particularly well defined; appearing like a flat oval ring. The central opening is not entirely dark, but is filled with a faint, hazy light, uniformly spread over it, like a fine gauze stretched over a hoop.

255. *Planetary nebulæ* are very extraordinary objects. They have, as their name imports, the appearance of planets, with round or slightly oval discs, somewhat mottled, but approaching, in some instances, to the vividness of actual planets. Some of them, upon the supposition that they are equally distant from us with the stars, must be of enormous magnitude. That one, for instance, which is situated in the left hand of Aquarius, must

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252. What remarkable nebula mentioned? Describe it? Point out on the map. 253. What other? How long known, and why? Show on the map. How described by Marius? Its form and extent? How considered? 254. What are *Annular Nebulæ*? are they common? What specimen referred to? 255. Planetary nebulæ? Their character and magnitude? Specimen? Stellar nebulæ? General remarks respecting

have a volume vast enough, upon the lowest computation, to fill the whole orbit of Herschel!

In some instances a nebula presents the appearance of a faint, luminous atmosphere, of a circular form, and of large extent, surrounding a central star of considerable brilliancy. These are denominated *Stellar Nebulæ.*

The nebulæ furnish an inexhaustible field of speculation and conjecture. That by far the larger number of them consists of stars, there can be little doubt; and in the interminable range of system upon system, and firmament upon firmament, which we thus catch a glimpse of, the imagination is bewildered and lost. Sir William Herschel conjectured that the nebulæ might form the material out of which nature elaborated new suns and systems, or replenished the wasted light of older ones. But the little we know of the physical constitution of these sidereal masses, is altogether insufficient to warrant such a conclusion. (For a Spiral Nebula recently discovered by Lord Rosse, see Map IX., Fig. 68.)

CHAPTER XIV.

VIA LACTEA (THE MILKY-WAY).

"Throughout the Galaxy's extended line,
Unnumber'd orbs in gay confusion shine:
Where every star that gilds the gloom of night
With the faint tremblings of a distant light,
Perhaps illumes some system of its own,
With the strong influence of a radiant sun."—*Mrs. Carter.*

256. THE VIA LACTEA, or *Milky-Way*, is that luminous zone or pathway of singular whiteness, varying from 4° to 20° in width, which passes quite around the heavens. The Greeks called it GALAXY, on account of its color and appearance: the Latins, for the same reason, called it VIA LACTEA, which, in our tongue, is *Milky-Way.*

Of all the objects which the heavens exhibit to our view, this fills the mind with the most indescribable grandeur and amazement. When we consider what unnumbered millions of mighty suns compose this stupendous girdle, whose distance is so vast that the strongest telescope can hardly separate their mingled twilight into distinct specks, and that the most contiguous of any two of them may be as far asunder as our sun is from them, we fall as far short of adequate language to express our ideas of such immensity, as we do of instruments to measure its boundaries.

257. It is one of the achievements of astronomy that has resolved the Milky-Way into an infinite number of small stars, whose confused and feeble luster occasions that peculiar whiteness which we see in a clear evening, when the moon is absent. It is also a recent and well-accredited doctrine of astronomy,

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the Nebulæ? Sir Wm. Herschel's conjecture? 256. What is the Via Lactea? Its Greek name? What said of its magnificence and grandeur? 257. What said of the achievements of astronomy? Its doctrine respecting the structure of the universe? Of the sun, and its relation to the fixed stars?

that all the stars in the universe are arranged into clusters, or groups, which are called NEBULÆ OR STARRY SYSTEMS, each of which consists of myriads of stars.

The fixed star which we call OUR SUN, belongs, it is said, to that extensive nebula, the Milky-Way; and although apparently at such an inmeasurable distance from its fellows is, doubtless, as near to any one of them, as they are to one another.

258. Of the number and economy of the stars which compose this group, we have very little exact knowledge. Dr. Herschel informs us that, with his best glasses, he saw and counted 588 stars in a single spot, without moving his telescope; and as the gradual motion of the earth carried these out of view and introduced others successively in their places, while he kept his telescope steadily fixed to one point, "there passed over his field of vision, in the space of one quarter of an hour, no lest than *one hundred and sixteen thousand stars*, and at another time, in forty-one minutes, no less than *two hundred and fifty-eight thousand.*"

In all parts of the Milky-Way he found the stars unequally dispersed, and appearing to arrange themselves into separate clusters. In the small space for example, between Beta and Sad'r, in Cygni, the stars seem to be clustering in two divisions; each division containing upwards of one hundred and sixty-five thousand stars. At other observations, when examining a section of the Milky-Way, not apparently more than a yard in breadth, and six in length, he discovered *fifty thousand* stars, large enough to be distinctly counted; and he suspected twice as many more, which, for want of sufficient light in his telescope, he saw only now and then.

259. It appears from numerous observations, that various changes are taking place among the nebulæ—that several nebulæ are formed by the disolution of larger ones, and that many nebulæ of this kind are at present detaching themselves from the Milky-Way. In that part of it which is in the body of Scorpio, there is a large opening, about 4° broad, almost desti tute of stars. These changes seem to indicate that mighty movements and vast operations are continually going on in the distant regions of the universe, upon a scale of magnitude and grandeur which baffles the human understanding.

More than two thousand five hundred nebulæ have already been observed; and, if each of them contains as many stars as the Milky-Way, several hundreds of millions of stars must exist, even within that portion of the heavens which lies open to our observation.

"O what a confluence of ethereal fires.
From urns unnumber'd down the steep of heaven
Streams to a point, and centers on my sight."

260. Although the Milky-Way is more or less visible at all seasons of the year, yet it is seen to the best advantage during

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258. Number and economy of the stars? Dr. Herschel's statements? What number passed the field of his instrument in a quarter of an hour? In forty-one minutes? In space apparently only a yard in breadth? 259. What changes observed in the nebulæ? What do they indicate? Number of nebulæ? Estimated number of stars? 260. When is the Via Lactea seen to the best advantage? Direction when Lyra is on the

the months of July, August, September, and October. When Lyra is on, or near the meridian; it may be seen stretching obliquely over the heavens from northeast to southwest, gradually moving over the firmament in common with other constellations. (For views of our cluster, see Map IX., Figs. 69, 70, 71.)

Its form, breadth and appearance are various, in different parts of its course. In some places it is dense and luminous; in others, it is scattered and faint. Its breadth is often not more than five degrees; though sometimes it is ten or fifteen degrees, and even twenty. In some places it assumes a double path, but for the most part it is single.

It may be traced in the heavens, beginning near the head of Cepheus, about 30° from the north pole, through the constellations Cassiopeia, Perseus, Auriga, and part of Orion and the feet of Gemini, where it crosses the Zodiac; thence over the equinoctial into the southern hemisphere, through Monoceros, and the middle of the ship Argo, where it is most luminous, Charles' Oak, the Cross, the feet of the Centaur, and the Altar. Here it is divided into two branches, as it passes over the Zodiac again into the northern hemisphere. One branch runs through the tail of Scorpio, the bow of Sagittarius, the shield of Sobieski, the feet of Antinous, Aquila, Delphinus, the Arrow and the Swan. The other branch passes through the upper part of the tail of Scorpio, the side of Serpentarius, Taurus Poniatowskii, the Goose and the neck of the Swan, where it again unites with the other branch, and passes on to the head of Cepheus, the place of its beginning.

Some of the pagan philosophers maintained that the Milky-Way was formerly the sun's path, and that its present luminous appearance is the track which its scattered beams left visible in the heavens.

The ancient poets, and even philosophers, speak of the Galaxy, or Milky-Way, as the path which their deities used in the heavens, and which led directly to the throne of Jupiter. Thus, Ovid, in his Metamorphoses, Book i.:—

> "A way there is in heaven's extended plain,
> Which, when the skies are clear, is seen below,
> And mortals, by the name of Milky, know;
> The groundwork is of stars, through which the road
> Lies open to the Thunderer's abode."

Milton alludes to this in the following lines:—

> "A broad and ample road, whose dust is gold,
> And pavement, stars, as stars to thee appear,
> Seen in the Galaxy, that Milky-Way,
> Which nightly as a circling zone, thou seest
> Powdered with stars."

CHAPTER XV.

ORIGIN OF THE CONSTELLATIONS.

261. The science of astronomy was cultivated by the immediate descendants of Adam. Josephus informs us that the sons of Seth employed themselves in the study of astronomy; and that they wrote their observations upon two pillars, one of brick

meridian? Its form, breadth, &c.? How traced in the heavens? Notion of the Pagan philosophers? Of the poets? What citations? 261. How early was astronomy cultivated?

and the other of stone,* in order to preserve them against the destruction which ADAM had foretold should come upon the earth.

He also relates, that Abraham argued the unity and power of God, from the orderly course of things both at sea and land, in their times and seasons, and from his observations upon the motions and influences of the sun, moon and stars; and that he read lectures in astronomy and arithmetic to the Egyptians, of which they understood nothing till Abraham brought these sciences from Chaldea to Egypt; from whence they passed to the Greeks.

262. BEROSUS also observes that Abraham was a great and just man, and famous for his celestial observations; the making of which was thought to be so necessary to the human welfare, that he assigns it as the principal reason of the Almighty's prolonging the life of man.

This ancient historian tells us, in his account of the longevity of the antediluvians, that Providence found it necessary to prolong man's days, in order to promote the study and advancement of virtue, and the improvement of geometry and astronomy, which required, at least, six hundred years for making and perfecting observations.†

263. When Alexander took Babylon, Calisthenes found that the most ancient observations existing on record in that city, were made by the Chaldeans about 1903 years before that period, which carries us back to the time of the dispersion of mankind by the confusion of tongues. It was 1500 years after this that the Babylonians sent to Hezekiah, to inquire about the shadow's going back on the dial of Ahaz.

It is, therefore, very probable that the Chaldeans and Egyptians were the original inventors of astronomy; but at what period of the world they marked out the heavens into constellations, remains in uncertainty. La Place fixes the date thirteen or fourteen hundred years before the Christian era, since it was about this period that Eudoxus constructed the first celestial sphere upon which the constellations were delineated. Sir Isaac Newton was of opinion, that all the old constellations related to the Argonautic expedition, and that they were invented to commemorate the heroes and events of that memorable enterprise. It should be remarked, however, that while none of the ancient constellations refer to transactions of a later date, yet we have various accounts of them of a much higher antiquity than that event.

264. Some of the most learned antiquarians of Europe have searched every page of heathen mythology, and ransacked all the legends of poetry and fable for the purpose of rescuing this subject from that impermeable mist which rests upon it, and they have only been able to assure us, in general terms, that they are Chaldean or Egyptian hieroglyphics, intended to perpetuate, by means of an imperishable record, the memory of the times in which their inventors lived, their religion and manners,

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* Josephus affirms, that "he saw himself that of stone to remain in Syria in his own time."

† Vince's Complete System of Astronomy, Vol. ii. p. 244.

What proof? What said of Abraham? 262. What further proof? What reason assigned for the longevity of the antediluvians? 263. What discovery by Calisthenes? What conclusion from this discovery? La Place's date of the origin of the constellations? Sir Isaac Newton's opinion? Remark? 264. What researches, and what results?

their achievements in the arts, and whatever in their history was most worthy of being commemorated. There was, at least, a moral grandeur in this idea; for an event thus registered, a custom thus canonized, or thus enrolled among the stars, must needs survive all other traditions of men, and stand forth in perpetual characters to the end of time.

265. In arranging the constellations of the Zodiac, for instance, it would be natural for them, we may imagine, to represent those stars which rose with the sun in the spring of the year, by such animals as the shepherds held in the greatest esteem at that season; accordingly, we find Aries, Taurus, and Gemini, as the symbols of March, April, and May.

266. When the sun enters the sign Cancer, at the summer solstice, he discontinues his progress towards the north pole, and begins to return towards the south pole. This retrograde motion was fitly represented by a Crab, which is said to go backward. The sun enters this sign about the 22d of June.

The heat which usually follows in the next month was represented by the Lion; an animal remarkable for its fierceness, and which at this season was frequently impelled by thirst to leave the sandy desert, and make its appearance on the banks of the Nile.

267. The sun entered the sixth sign about the time of harvest, which season was therefore represented by a Virgin, or female reaper, with an ear of corn in her hand.

At the autumnal equinox, when the sun enters Libra, the days and nights are equal all over the world, and seem to observe an equilibrium or balance. The sign was therefore represented under the symbol of a pair of Scales.

268. Autumn, which produces fruit in great abundance, brings with it a variety of diseases, and on this account was represented by that venomous animal, the Scorpion, which, as he recedes, wounds with a sting in his tail. The fall of the leaf, was the season for hunting, and the stars which mark the sun's path at this time were represented by a huntsman, or archer, with his arrows and weapons of destruction.

The Goat, which delights in climbing and ascending some mountain or precipice, is the emblem of the winter solstice, when the sun begins to ascend from the southern tropic, and gradually to increase in height for the ensuing half year.

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265. Origin of Aries, Taurus, and Gemini? 266. Of Cancer and Leo? 267. Of Virgo and Libra? 268. Of Scorpio and Capricorn?

269. Aquarius, or the Water-Bearer, is represented by the figure of a man pouring out water from an urn, an emblem of the dreary and uncomfortable season of winter.

The last of the zodiacal constellations was Pisces, or a couple of fishes, tied back to back, representing the fishing season. The severity of winter is over ; the flocks do not afford sustenance, but the seas and rivers are open and abound with fish.

"Thus monstrous forms, o'er heaven's nocturnal arch,
Seen by the sage, in pomp celestial march;
See Aries there his glittering bow unfold,
And raging Taurus toss his horns of gold;
With bended bow the sullen Archer lowers,
And there Aquarius comes with all his showers;
Lions and Centaurs, Gorgons, Hydras rise,
And gods and heroes blaze along the skies."

Whatever may have led to the adoption of these rude names at first, they are now retained to avoid confusion.

The early Greeks, however, displaced many of the Chaldean constellations, and substituted such images in their place as had a more special reference to their own history. The Romans also pursued the same course with regard to *their* history; and hence the contradictory accounts that have descended to later times.

270. Some, moreover, with a desire to divest the science of the stars of its pagan jargon and profanity, have been induced to alter both the names and figures of the constellations. In doing this, they have committed the opposite fault; that of blending them with things sacred.

The "venerable Bede," for example, instead of the profane names and figures of the twelve constellations of the Zodiac, substituted those of the *twelve apostles.* Julius Schillerius, following his example, completed the reformation in 1627, by giving Scripture names to all the constellations in the heavens.

Weigelius, too, a celebrated professor of mathematics in the University of Jena, made a new order of constellations, by converting the firmament into a CŒLUM HERALDICUM, in which he introduced the arms of all the princes of Europe. But astronomers, generally, never approved of these innovations; and for ourselves, we had as lief the sages and heroes of antiquity should continue to enjoy their fianced honors in the sky, as to see their places supplied by the princes of Europe.

271. The number of the old constellations, including those of the Zodiac, was only forty-eight. As men advanced in the knowledge of the stars, they discovered many, but chiefly in southern latitudes, which were not embraced in the old constellations, and hence arose that mixture of ancient and modern names which we meet with in modern catalogues.

272. Astronomers divide the heavens into three parts, called the Northern and Southern Hemispheres, and the Zodiac. In the

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269. Of Aquarius and Pisces? Course of the Greeks and Romans, in displacing constellations? 270. What other reform attempted? What particular instances cited? Bede? Schillerius? Weigelius? How are these innovations regarded by astronomers? 271. Number of the old constellations? How others added? 272. How do astrono

northern hemisphere, astronomers usually reckon thirty-four constellations, in the Zodiac twelve, and in the southern hemisphere forty-seven ; making in all ninety-three. Besides these, there are a few of inferior note, recently formed, which are not considered sufficiently important to be particularly described.

273. About the year 1603, John Bayer, a native of Germany, invented the convenient system of denoting the stars in each constellation by the letters of the Greek alphabet, applying to the largest star the first letter of the alphabet ; to the next largest the second letter, and so on to the last. Where there are more stars in the constellation than there are Greek letters, the remainder are denoted by the letters of the Roman alphabet, and sometimes by figures.

By this system of notation, it is now as easy to refer to any particular star in the heavens, as to any particular house in a populous city, by its street and number. Before this practice was adopted, it was customary to denote the stars by referring them to their respective *situations in the figure* of the constellation to which they severally belonged, as the head, the arm, the foot, &c.

It is hardly necessary to remark that these figures, which are all very curiously depicted upon artificial globes and maps, are purely a fanciful invention—answering many convenient ends, however, for purposes of reference and classification, as they enable us to designate with facility any particular star, or cluster of stars; though these clusters very rarely, if ever, represent the real figures of the objects whose names they bear. And yet it is somewhat remarkable that the name of "Great Bear," for instance, should have been given to the very *same* constellation by a nation of American aborigines (the Iroquois), and by the most ancient Arabs of Asia, when there never had been any communication between them! Among other nations, also, between whom there exists no evidence of any intercourse, we find the Zodiac divided into the same number of constellations, and these distinguished by nearly the same names, representing the twelve months, or seasons of the year.

274. The constellations, or the uncouth figures by which they are represented, are a faithful picture of the ruder stages of civilization. They ascend to times of which no other record exists ; and are destined to remain when all others shall be lost. Fragments of history, curious dates and documents relating to chronology, geography and languages, are here preserved in imperishable characters.

The adventures of the gods, and the inventions of men, the exploits of heroes, and the fancies of poets, are here spread out in the heavens, and perpetually celebrated before all nations. The Seven stars, and Orion, present themselves to us, as they appeared to Amos and Homer: as they appeared to Job, more than 3000 years ago, when the Almighty demanded of him—"Knowest thou the ordinances of heaven? Canst thou bind the sweet influences of the PLEIADES, or loose the bands of ORION? Canst thou bring forth MAZZAROTH in his season, or canst thou guide ARCTURUS with his sons?" Here, too, are consecrated the lyre of Orpheus and the ship of the Argonauts; and, in the same firmament, glitter the Mariner's Compass and the Telescope of Herschel.

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mers divide the constellations? Number in each division? Total? What others? 273. John Bayer's invention? Utility of it? How before it was adopted? What remark respecting the figures on maps and globes, and their use? What remarkable facts stated? 274. Historical use of the constellations? Illustrations?

CHAPTER XVI.

NUMBER, DISTANCE AND ECONOMY OF THE STARS.

275. The first conjecture in relation to the distance of the fixed stars is, that they are all placed at an equal distance from the observer, upon the visible surface of an immense concave vault, which rests upon the circular boundary of the world, and which we call the *Firmament*. We can, with the unassisted eye, form no estimate of their respective distances; nor has the telescope yet enabled us to arrive at any exact results on this subject, although it has revealed to us many millions of stars that are as far removed beyond those which are barely visible to the naked eye, as these are from us.

Viewed through the telescope, the heavens become quite another spectacle—not only to the understanding but to the senses. New worlds burst upon the sight, and old ones expand to a thousand times their former dimensions. Several of those little stars which but feebly twinkle on the unassisted eye, become immense globes, with land and water, mountains and valleys, encompassed by atmospheres, enlightened by moons, and diversified by day and night, summer and winter.

Beyond these are other suns, giving light and life to other systems, not a thousand, or two thousand merely, but multiplied without end, and ranged all around us, at immense distances from each other, attended by ten thousand times ten thousand worlds, all in rapid motion; yet calm, regular and harmonious—all space seems to be illuminated, and every particle of light a world.

276. It has been computed that *one hundred millions* of stars which cannot be discerned by the naked eye, are now visible through the telescope. And yet all this vast assemblage of suns and worlds may bear no greater proportion to what lies beyond the utmost boundaries of human vision, than a drop of water to the ocean; and, if stricken out of being, would be no more missed, to an eye that could take in the universe, than the fall of a single leaf from the forest.

We should therefore learn, says Dr. Chalmers, not to look on our earth as the universe of God, but as a single, insignificant atom of it; that it is only one of the many mansions which the Supreme Being has created for the accommodation of his worshipers; and that he may now be at work in regions more distant than geometry ever measured, creating worlds more manifold than numbers ever reckoned, displaying his goodness, and spreading over all the intimate visitations of his care.

277. The immense distance at which the nearest stars are known to be placed, proves that they are bodies of a prodigious size, not inferior to our sun, and that they shine, not by reflected rays, but by their own native light. It is therefore concluded,

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275. What is the first conjecture as to the distance of the stars? Can we form no just estimate? What said of the heavens when seen through a telescope? 276. What computation as to the number of stars invisible to the naked eye, but visible through telescopes? Is this probably the whole universe? Remark of Chalmers? 277. What

with good reason, that every fixed star is a sun, no less spacious than ours, surrounded by a retinue of planetary worlds, which revolve around it as a center, and derive from it light and heat, and the agreeable vicissitudes of day and night.

These vast globes of light, then, could never have been designed merely to diversify the voids of infinite space, nor to shed a few glimmering rays on our far distant world, for the amusement of a few astronomers, who, but for the most powerful telescopes, had never seen the ten thousandth part of them. We may therefore rationally conclude, that *wherever* the All-wise Creator has exerted his creative power, *there* also he has placed intelligent beings to adore his goodness.

278. The greatest possible ingenuity and pains have been taken by astronomers to determine, at least, the approximate distance of the nearest fixed stars. If they have hitherto been unable to arrive at any satisfactory result, they have, at least, established a limit beyond which the stars must necessarily be placed. If they have failed to calculate their true distances from the earth, it is because they have not the requisite data. The solution of the problem, if they had the data, would not be more difficult than to compute the relative distances of the planets—a thing which any schoolboy can do.

In estimating so great a distance as the nearest fixed star, it is necessary that we employ the longest measure which astronomy can use. Accordingly, we take the whole diameter of the earth's orbit, which, in round numbers, is 190 millions of miles, and endeavor, by a simple process in mathematics, to ascertain how many measures of this length are contained in the mighty interval which separates us from the stars.

The method of doing this can be explained to the apprehension of the pupil, if he does not shrink from the illustration, through an idle fear that it is beyond his capacity.

For example ; suppose that, with an instrument constructed for the purpose, we should this night take the precise bearing or angular direction from us of some star in the northern hemisphere, and note it down with the most perfect exactness, and, having waited just six months, when the earth shall have arrived at the opposite point of its orbit, 190 millions of miles east of the place which we now occupy, we should then repeat our observation upon the same star, and see how much it had changed its position by our traveling so great a distance one side of it. Now, it is evident, that if it changes its apparent position at all, the *quantity* of the change will bear some proportion to the distance gone over ; that is, the *nearer* the star, the *greater* the angle ; and the more *remote* the star, the *less* the angle. It is to be observed, that the angle thus found, is called the star's *Annual Parallax.*

279. But it is found by the most eminent astronomers of the age, and the most perfect instruments ever made, that the parallax of the nearest stars does not exceed the *four thousandth part of a degree*, or a single second ; so that, if the whole great orbit of the earth were lighted up into a globe of fire 600 millions of miles in circumference, it would be seen by the nearest star only as a twinkling atom ; and to an observer placed at this distance,

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proof that the stars are large bodies? What conclusion, therefore? What other inference? 278. What effort to determine the *distances* of the stars? What results? What necessary in estimating the distances of the stars? What measure taken? Describe the process of determining the distance of the stars by *parallax.* 279. What is the parallax of the stars found to be, and what follows as a consequence? What, our sun, with its whole retinue of planetary worlds, would occupy a space scarcely exceeding the thickness of a spider's web.*

If the nearest of the fixed stars are placed at such inconceivable distances in the regions of space, with what line shall we measure the distance of those which are a thousand or a million of times as much farther from them, as these are from us?

280. If the annual parallax of a star were accurately known, it would be easy to compute its distance by the following rule :

As the sine of the star's parallax :
Is to radius, or ninety degrees : :
So is the earth's distance from the sun :
To the star's distance from the sun.

If we allow the annual parallax of the nearest star to be 1″, the calculation will be,

As 0.0000048481368=Nat. Sine of 1″.
Is to 1.0000000000000=Nat. Sine of 90°.
So is 95,273,868.867748554=Earth's distance from the sun.
To 19,651,627,683,449=Star's distance from the sun.

In this calculation we have supposed the earth to be placed at the mean distance of 24,047 of its own semi-diameters, or 95,273,868.867748554 miles from the sun, which makes the star's distance a very little less than twenty billions of miles. Dr. Herschel says that Sirius cannot be nearer than 100,000 times the diameter of the earth's orbit, or 19,007,788,800,000 of miles.

Biot, who either takes the earth's distance *greater* than he lays it down in his *Traité Elementaire d'Astronomie Physique*, or has made an error in figures, makes the distance 20,086,868,036,404. Dr. Brewster makes it 20,159,665,000,000 miles. A mean of these computations, is 20 billions; that is, 20 millions of millions of miles to a parallax of 1″.

Astronomers are generally agreed in the opinion that the annual parallax of the stars is less than 1″, and consequently that the nearest of them is placed at a much greater distance from us, than these calculations make it. It was, however, announced in 1832, that M. d'Assas, a French astronomer, had satisfactorily established the annual parallax of *Keid* (a small star 8° N. of Gamma Eridani), to be 2″, that of *Rigel*, in Orion, to be 1″.43, and that of *Sirius* to be 1″.24. If these results could be relied on, Keid would be but 10 billions, Rigel but 14 billions, and Sirius 16 billions of miles from the earth. This latter distance is, however, so great that, if Sirius were to fall toward the earth at the rate of a million of miles a day, it would take it forty-three thousand, three hundred years to reach the earth; or, if the Almighty were now to blot it out of the heavens, its brilliance would continue undiminished in our hemisphere for the space of three years to come.

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* A just idea of the import of this term, will impart a force and sublimity to an expression of St. James, which no power of words could improve. It is said, chapter i. verse 17, of Him from whom cometh down every good and perfect gift, that there is "ουκ ενι παραλλαγη η τροπης αποσκιασμα." Literally, there is "*neither parallax nor shadow of change*:" As if the apostle had said—Peradventure, that in traveling millions and millions of miles through the regions of immensity, there may be a sensible parallax to some of the fixed stars; yet, as to the Father of Lights, view him from whatever point of his empire we may, *he is without parallax or shadow of change!*

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then, of the more distant stars? 280. How deduce the distance of a star from its parallax, if known? Computation laid down? Dr. Herschel's remark? Biot's estimate? Dr. Brewster's? The mean of these three estimates? Are astronomers agreed as to the parallax of the stars? M. d'Assas' computations and results?

281. The most brilliant stars, till recently, were supposed to be situated nearest the earth, but later observations prove that this opinion is not well founded, since some of the smaller stars appear to have not only a greater annual parallax, but an absolute motion in space, much greater than those of the brightest class.

282. It has been computed that the light of Sirius, although twenty thousand million times less than that of our sun, is nevertheless three hundred and twenty-four times greater than that of a star of the 6th magnitude. If we suppose the two stars to be really of the same size, it is easy to show that the star of the sixth magnitude is fifty-seven and one-third times farther from us than Sirius is, because light diminishes as the square of the distance of the luminous body increases.

By the same reasoning it may be shown, that if Sirius were placed where the sun is, it would appear to us to be four times as large as the sun, and give four times as much light and heat. It is by no means unreasonable to suppose, that many of the fixed stars exceed a million of miles in diameter.

283. We may pretty safely affirm, then, that stars of the sixth magnitude are not less than nine hundred millions of millions of miles distant from us ; or a million of times farther from us than the planet Saturn, which is scarcely visible to the naked eye. But the human mind in its present state can no more appreciate such distances than it can infinity ; for if our earth, which moves at more than the inconceivable velocity of a million and a half of miles a day, were to be hurried from its orbit, and to take the same rapid flight over this immense tract, it would not traverse it in sixteen hundred thousand years ; and every ray of light, although it moves at the rate of one hundred and ninety-three thousand miles in a single second of time, is more than one hundred and seventy years in coming from the star to us.

But what is even this, compared with that measureless extent which the discoveries of the telescope indicate? According to Dr. Herschel, the light of some of the nebulæ, just perceptible through his 40 feet telescope, must have been a million of ages in coming to the earth; and should any of them be now destroyed, they would continue to be perceptible for a million of ages to come.

Dr. Herschel informs us, that the glass which he used would separate stars at 497 times the distance of Sirius.

284. It is one of the wonders of creation, that any phenomena of bodies at such an immense distance from us should be perceptible by human sight ; but it is a part of the Divine Maker's

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281. Former supposed relative distance of the most brilliant stars? Present opinion, and on what founded? 282. What computation as to the light of Sirius? What conclusion as to the *distance* of other stars? How, then, would he appear if as near as our sun? What conclusion as to the magnitude of the stars? 283. Distance of the sixth magnitude stars? How measured by the flight of the earth? Of light? What further estimate by Dr. Herschel? 284. What remark respecting our knowledge of the stars

plan, that although they do not act physically upon us, yet they should so far be objects of our perception, as to expand our ideas of the vastness of the universe, and of the stupendous extent and operations of his omnipotence.

"With these facts before us," says an eminent astronomer and divine, "it is most reasonable to conclude, that those expressions in the Mosaic history of Creation, which relate to the creation of the fixed stars, are not to be understood as referring to the *time* when they were brought into existence, as if they had been created about the same time with our earth; but as simply declaring the fact, that, at whatever period in duration they were created, *they derived their existence from God.*"

285. "That the stars here mentioned" (*Gen.* i. 16), says a distinguished commentator, "were the planets of our system, and not the fixed stars, seems a just inference from the fact, that after mentioning them, Moses immediately subjoins, 'And Elohim set them in the firmament of the heaven to give light upon the earth, and to rule over the day and over the night;' evidently alluding to Venus and Jupiter, which are alternately our morning and evening stars, and which 'give light upon the earth,' far surpassing in brilliancy any of the fixed stars."

However vast the universe now appears, however numerous the worlds which may exist within its boundless range, the language of Scripture, and Scripture alone, is sufficiently comprehensive and sublime to express all the emotions which naturally arise in the mind when contemplating its structure. This shows not only the harmony which subsists between the discoveries of the Revelation and the discoveries of Science, but also forms, by itself, a strong presumptive evidence, that the records of the Bible are authentic and divine.

286. We have hitherto described the stars as being immovable and at rest; but from a series of observations on double stars, Dr. Herschel found that a great many of them have changed their situations with regard to each other; that some perform revolutions about others, at known and regular periods, and that the motion of some is direct, while that of others is retrograde; and that many of them have dark spots upon their surface, and turn on their axes, like the sun.

287. A remarkable change appears to be gradually taking place in the relative distances of the stars from each other in the constellation Hercules. The stars in this region appear to be spreading farther and farther apart, while those in the opposite point of the heavens seem to close nearer and nearer together, in the same manner as when walking through a forest, the trees toward which we advance appear to be constantly separating, while the distance between those which we leave behind is gradually contracting.

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by sight? How are we to understand Moses as to the time of the creation of the stars? 285. What meant by the "stars" mentioned Gen. i., 16? What proof? Remark respecting the Scriptures? 286. How have the stars been described hitherto? What is the fact? 287. What example cited? What astonishing conclusion?

From this appearance it is concluded, that the sun, with all its retinue of planetary worlds, is moving through the regions of the universe, toward some distant center, or around some wide circumference at the rate of near thirty thousand miles an hour; and that it is therefore highly probable, if not absolutely certain, that we shall never occupy that portion of *absolute space*, through which we are at this moment passing, during all the succeeding ages of eternity.

288. The direction of the Sun's motion is towards the constellation of Hercules; R. A. 259°; Dec. 35°. This *velocity* in space is estimated at 8 miles per second, or 28,000 miles per hour. His period is about 18,200,000 years; and the arc of his orbit, over which he has traveled since the creation of the world, amounts to only about $\frac{1}{3000}$th part of his orbit, or about 7 minutes—an arc so small, compared with the whole, as to be hardly distinguishable from a straight line.

With this wonderful fact in view, we may no longer consider the sun as fixed and stationary, but rather as a vast and luminous *planet*, sustaining the same relation to some central orb that the primary planets sustain to him, or that the secondaries sustain to their primaries. Nor is it necessary that the stupendous mechanism of nature should be restricted even to these sublime proportions. The sun's central body may also have its orbit, and its center of attraction and motion, and so on, till, as Dr. Dick observes, we come to the great center of all—to the THRONE OF GOD!

Professor Mädler, of Dorpat, in Russia, has recently announced as a discovery that the star *Alcyone*, one of the seven stars, is the *center* around which the sun and solar system are revolving.

289. Dr. Dick, the author of the CHRISTIAN PHILOSOPHER, endeavors to convey some idea of the boundless extent of the universe, by the following sublime illustration:—

"Suppose that one of the highest order of intelligences is endowed with a power of rapid motion superior to that of light, and with a corresponding degree of intellectual energy; that he has been flying without intermission, from one province of creation to another, for six thousand years, and will continue the same rapid course for a thousand million years to come, it is highly probable, if not absolutely certain, that, at the end of this vast tour, he would have advanced no farther than the 'suburbs of creation,'—and that all the magnificent systems of material and intellectual beings he had surveyed, during his rapid flight, and for such a length of ages, bear no more proportion to the whole empire of Omnipotence, than the smallest grain of sand does to all the particles of matter contained in ten thousand worlds."

Were a seraph, in prosecuting the tour of creation in the manner now stated, ever to arrive at a limit beyond which no farther displays of the Divinity could be perceived, the thought would overwhelm his faculties with unutterable emotions; he would feel that he had now, in some measure, comprehended all the plans and operations of Omnipotence, and that no farther manifestation of the Divine glory remained to be explored. But we may rest assured that this can never happen in the case of any created intelligence.

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288. The direction and velocity of the sun? Period? Arc of orbit passed over since creation? How, then, should we consider the sun? View of the universe? Discovery of Professor Madler? 289. Dr. Dick's illustrations?

290. There is, moreover, an argument derivable from the laws of the physical world, that seems to strengthen, I had almost said, to confirm, this idea of the Infinity of the material universe. It is this—If the number of stars be finite, and occupy only a part of space, the outward stars would be continually attracted to those within, and in time would unite in one. But if the number be infinite, and they occupy an infinite space, all parts would be nearly in equilibrio, and consequently each fixed star, being equally attracted in every direction, would keep its place.

No wonder, then, that the Psalmist was so affected with the idea of the immensity of the universe, that he seems almost afraid lest he should be overlooked amidst the immensity of beings that must needs be under the superintendence of God; nor that any finite mortal should exclaim, when contemplating the heavens—"What is *man*, that THOU art mindful of him!"

CHAPTER XVII.

FALLING, OR SHOOTING STARS.

291. THE phenomenon of shooting stars, as it is called, is common to all parts of the earth; but is most frequently seen in tropical regions. The unerring aim, the startling velocity, and vivid brightness with which they seem to dart athwart the sky, and as suddenly expire, excite our admiration; and we often ask, "What can they be?"

But frequent as they are, this interesting phenomenon is not well understood. Some imagine that they are occasioned by electricity, and others, that they are nothing but luminous gas. Others again have supposed, that some of them are luminous bodies which accompany the earth in its revolution around the sun, and that their return to certain places might be calculated with as much certainty and exactness as that of any of the comets.

292. Dr. Burney, of Gosport, kept a record of all that he observed in the course of several years. The number which he noticed in 1819 was 121, and in 1820 he saw 131. Professor

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290. What argument supposed to favor the idea of a *boundless* universe? Allusion to the Psalmist? 291. Where are shooting stars most common? Are they well understood? What theories stated? 292. Dr. Burney's record? Professor Green's opinion? Signior Baccaria's opinion, and his reasons for it?

Green is confident that a much larger number are annually seen in the United States.

Signior Baccaria supposed they were occasioned by electricity, and thinks this opinion is confirmed by the following observations. About an hour after sunset, he and some friends, that were with him, observed a falling star directing its course directly toward them, and apparently growing larger and larger, but just before it reached them it disappeared. On vanishing, their faces, hands, and clothes, with the earth and all the neighboring objects, became suddenly illuminated with a diffused and lambent light. It was attended with no noise. During their surprise at this appearance, a servant informed them that he had seen a light shine suddenly in the garden, and especially upon the streams which he was throwing to water it.

The Signior also observed a quantity of electric matter collect about his kite, which had very much the appearance of a falling star. Sometimes he saw a kind of halo accompanying the kite, as it changed its place, leaving some glimmering of light in the place it had quitted.

293. Shooting stars have been supposed by those meteorologists who refer them to electricity or luminous gas, to prognosticate changes in the weather, such as rain, wind, &c.; and there is, perhaps, some truth in this opinion. The duration of the brilliant track which they leave behind them, in their motion through the air, will probably be found to be longer or shorter, according as watery vapor abounds in the atmosphere.

The notion that this phenomenon betokens high winds, is of great antiquity. Virgil, in the first book of his Georgics, expresses the same idea:—

"Sæpe etiam stellas vento impendente videbis
Præcipites cœlo labi; noctisque per umbram
Flammarum longos a tergo albescere tractus."

"And oft, before tempestuous winds arise,
The *seeming* stars fall headlong from the skies,
And shooting through the darkness, gild the night
With sweeping glories and long trails of light."

294. The number of shooting stars observed in a single night, though variable, is commonly very small. There are, however, several instances on record of their falling in "showers"—when every star in the firmament seems loosened from its sphere, and moving in lawless flight from one end of the heavens to the other.

As early as the year 472, in the month of November, a phenomenon of this kind took place near Constantinople. As Theo-

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293. What are they supposed by some to prognosticate? What other ancient notion? Poetic quotation? 294. What said of the *number* of shooting stars? What instances of "meteoric showers" cited?

phanes relates, "the sky appeared to be on fire," with the coruscations of the flying meteors.

A shower of stars exactly similar took place in Canada, between the 3d and 4th of July, 1814, and another at Montreal, in November, 1819. In all these cases, a residuum, or *black dust*, was deposited upon the surface of the waters, and upon the roofs of buildings, and other objects. In the year 1810, "inflamed substances," it is said, fell into, and around lake Van, in Armenia, which stained the water of a blood color, and cleft the earth in various places. On the 5th of September, 1819, a like phenomenon was seen in Moravia. History furnishes many more instances of meteoric showers, depositing a *red dust* in some places, so plentiful as to admit of chemical analysis.

295. The commissioner (Mr. Andrew Ellicott), who was sent out by our government to fix the boundary between the Spanish possessions in North America and the United States, witnessed a very extraordinary flight of shooting stars, which filled the whole atmosphere from Cape Florida to the West India Islands. This grand phenomenon took place the 12th of November, 1799, and is thus described:—"I was called up," says Mr. Ellicott, "about 3 o'clock in the morning, to see the shooting stars, as they are called. The phenomenon was grand and awful. The whole heavens appeared as if illuminated with sky-rockets, which disappeared only by the light of the sun, after daybreak. The meteors, which at any one instant of time appeared as numerous as the stars, flew in all possible directions except *from* the earth, *toward* which they all inclined more or less, and some of them descended perpendicularly over the vessel we were in, so that I was in constant expectation of their falling on us."

Mr. Ellicott further states that his thermometer, which had been at 80° Fahr. for the four days preceding, fell to 56° about 4 o'clock, A. M., and that nearly at the same time, the wind changed from the south to the northwest, from whence it blew with great violence for three days without intermission.

These same appearances were observed the same night at Santa Fe de Bogota, Cumana, Quito, and Peru, in South America; and as far north as Labrador and Greenland, extending to Weimar in Germany, being thus visible over an extent on the globe of 64° of latitude, and 94° of longitude.

The celebrated Humboldt, accompanied by M. Bompland, then in S. America, thus speaks of the phenomenon:—"Toward the morning of the 13th of November, 1799, we witnessed a most extraordinary scene of shooting meteors. Thousands of *bolides*, and falling stars succeeded each other during four hours. Their direction was very regular from north to south. From the beginning of the phenomenon there was not a space in the firmament, equal in extent to three diameters of the moon, which was not filled every instant with *bolides* or falling stars. All the meteors left luminous traces, or phosphorescent bands behind them, which lasted seven or eight seconds."

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295. What phenomenon described by Mr. Ellicott? When and where? Effect on his thermometer? Where else observed, and by whom?

This phenomenon was witnessed by the Capuchin missionary at San Fernando de Afiura, a village situated in lat. 7° 53′ 12″, amidst the savannahs of the province of Varinas; by the Franciscan monks stationed near the cataracts of the Oronoco, and at Marca, on the banks of the Rio Negro, lat. 2° 40′, long. 70° 21′, and in the west of Brazil, as far as the equator itself; and also at the city of Porto Cabello, lat. 10° 6′ 52″, in French Guiana, Popayan, Quito, and Peru. It is somewhat surprising that the same appearances, observed in places so widely separated, amid the vast and lonely deserts of South America, should have been seen, the same night, in the United States, in Labrador, in Greenland, and at Itterstadt, near Weimar, in Germany!

296. We are told that thirty years before, at the city of Quito, "there was seen in one part of the sky, above the volcano of Cayamburo, so great a number of falling stars, that the mountain was thought to be in flames. This singular sight lasted more than an hour. The people assembled in the plain of Exida, where a magnificent view presents itself of the highest summits of the Cordilleras. A procession was already on the point of setting out from the convent of St. Francis, when it was perceived that the blaze on the horizon was caused by fiery meteors, which ran along the sky in all directions, at the altitude of 12 or 13 degrees."

297. But the most sublime phenomenon of shooting stars, of which the world has furnished any record, was witnessed throughout the United States on the morning of the 13th of November, 1833. The entire extent of this astonishing exhibition has not been precisely ascertained, but it covered no inconsiderable portion of the earth's surface. It has been traced from the longitude of 61°, in the Atlantic ocean, to longitude 100° in Central Mexico, and from the North American lakes to the West Indies. It was not seen, however, anywhere in Europe, nor in South America, nor in any part of the Pacific Ocean yet heard from.

Everywhere, within the limits above mentioned, the first appearance was that of fireworks of the most imposing grandeur, covering the entire vault of heaven with myriads of fire-balls, resembling sky-rockets. Their coruscations were bright, gleaming and incessant, and they fell thick as the flakes in the early snows of December. (See cut on the next page.)

To the splendors of this celestial exhibition, the most brilliant sky-rockets and fireworks of art bear less relation than the twinkling of the most tiny star to the broad glare of the sun. The whole heavens seemed in motion, and suggested to some the awful grandeur of the image employed in the apocalypse, upon the opening of the sixth seal, when "the stars of heaven fell unto the earth, even as a fig-tree casteth her untimely figs, when she is shaken of a mighty wind."

298. One of the most remarkable circumstances attending his display was, that the meteors all seemed to emanate from

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296. What other similar phenomenon cited? 297. What still more sublime spectacle? Its extent? Its appearance?

one and the same point, a little southeast of the zenith. Following the arch of the sky, they ran along with immense velocity, describing, in some instances, an arc of 30° or 40° in a few

METEORIC SHOWER OF NOVEMBER, 1833.

seconds. On more attentive inspection it was seen, that the meteors exhibited three distinct varieties ; the *first*, consisting of *phosphoric lines*, apparently described by a point ; the *second*, of large *fire-balls*, that at intervals darted along the sky, leaving luminous trains, which occasionally remained in view for a number of minutes, and, in some cases, for half an hour or more ; the third, of undefined *luminous bodies*, which remained nearly stationary in the heavens for a long time.

Those of the first variety were the most numerous, and resembled a shower of fiery snow driven with inconceivable velocity to the north of west. The second kind appeared more like *falling* stars—a spectacle which was contemplated by the more unenlightened beholders with great amazement and terror. The trains which they left were commonly white, but sometimes were tinged with various prismatic colors, of great beauty.

299. These fire-balls were occasionally of enormous size. Dr. Smith, of North Carolina, describes one which appeared larger than the full moon rising. "I was," says he, "startled by the

298. What remarkable circumstance attended this phenomenon? Variety of meteors?
299. What said of the fireballs seen? Of their size?

splendid light in which the surrounding scene was exhibited, rendering even small objects quite visible."

The same ball, or a similar one, seen at New Haven, passed off in a northwest direction, and exploded a little northward of the star Capella, leaving, just behind the place of explosion, a train of peculiar beauty. The line of direction was at first nearly straight; but it soon began to contract in length, to dilate in breadth, and to assume the figure of a serpent SCROLLING itself up, until it appeared like a luminous cloud of vapor, floating gracefully in the air, where it remained in full view for several minutes.

A LARGE METEOR.

If this body were at the distance of 110 miles from the observer, it must have had a diameter of one mile; if at the distance of 11 miles, its diameter was 528 feet; and if only one mile off, it must have been 48 feet in diameter. These considerations leave no doubt that many of the meteors were bodies of *large size*.

300. Of the third variety of meteors, the following are remarkable examples:—At Poland, Ohio, a luminous body was distinctly visible in the northeast for more than an hour. It was very brilliant, in the form of a *pruning-hook*, and apparently twenty feet long, and eighteen inches broad. It gradually settled toward the horizon, until it disappeared.

At Niagara Falls, a large luminous body, shaped like a *square table*, was seen near the zenith, remaining for some time almost stationary, emitting large streams of light.

301. The point from which the meteors seemed to emanate, was observed, by those who fixed its position among the stars, to be in constellation Leo; and, according to their concurrent testimony, this RADIANT POINT was stationary among the stars, during the whole period of observation; that is, it did not move along with the earth, in its diurnal revolution eastward, but accompanied the stars in their apparent progress westward.

A remarkable *change of weather*, from warm to cold, accompanied the meteoric shower, or immediately followed it. In all parts of the United States, this change was remarkable for its suddenness and intensity. In many places, the day preceding had been unusually warm for the season, but, before the next morning, a severe frost ensued, unparalleled for the time of year.

302. In attempting to explain these mysterious phenomena, it is argued, in the first place, *that the meteors had their origin beyond the limits of our atmosphere*; that they of course did not belong to this earth, but to the regions of space exterior to it.

300. What other variety of meteors described? Where? 301. Point from which they seemed to emanate? What change of weather followed? 302. What fact asserted as to the *distance* from which those meteors came? Professor Olmsted's estimate of distance?

The reason on which the conclusion is founded is this:—All bodies near the earth, including the atmosphere itself, have a common motion with the earth around its axis from west to east; but the *radiant point*, that indicated the source from which the meteors emanated, followed the course of the stars from east to west; therefore, it was independent of the earth's rotation, and consequently, at a great distance from it, and beyond the limits of the atmosphere. The *height* of the meteoric cloud, or radiant point, above the earth's surface, was, according to the mean average of Professor Olmsted's observations, not less than 2238 miles.

303. That the meteors were constituted of very light, combustible materials, seems to be evident, from their exhibiting the actual phenomena of combustion, they being consumed, or converted into smoke, with intense light; and the extreme tenuity of the substance composing them is inferred from the fact that they were stopped by the resistance of the air. Had their quantity of matter been considerable, with so prodigious a velocity, they would have had sufficient momentum to dash them upon the earth; where the most disastrous consequences might have followed.

The momentum of even light bodies of such size, and in such numbers, traversing the atmosphere with such astonishing velocity, must have produced extensive derangements in the atmospheric equilibrium. Cold air from the upper regions would be brought down to the earth; the portions of air incumbent over districts of country remote from each other, being mutually displaced, would exchange places, the air of the warm latitudes be transferred to colder, and that of cold latitudes to warmer regions.

304. Various *hypotheses* have been proposed to account for this wonderful phenomena. The agent which most readily suggests itself in this, and in many other unexplained natural appearances, is *electricity*. But no known properties of electricity are adequate to account for the production of the meteors, for their motions, or for the trains which they, in many instances, left behind them. Others, again, have referred their proximate cause to *magnetism*. and to *phosphureted hydrogen*; both of which, however, seem to be utterly insufficient, so far as their properties are known, to account for so unusual a phenomenon.

305. Professor Olmsted, of *Yale College*, who has taken much pains to collect facts, and to establish a permanent theory for the periodical recurrence of such phenomena, came to the conclusion, that—

The meteors of November 13th, 1833, *emanated from a nebulous body, which was then pursuing its way along with the earth around the sun; that this body continues to revolve around the sun, in an elliptical orbit—but little inclined to the plane of the ecliptic, and having its aphelion near the orbit of the earth; and finally, that*

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303. Supposed composition of these meteors? Why? 304. Hypotheses for explaining phenomenon? Are they satisfactory? 305. Professor Olmsted's conclusion?

*the body has a period of nearly six months, and that its perihelion is a little below the orbit of Mercury.**

This theory at least accommodates itself to the remarkable fact, that almost all the phenomena of this description, which are known to have happened, have occurred in the two opposite months of April and November. A similar exhibition of meteors to that of November, 1833, was observed on the same day of the week, April 20th, 1803, at Richmond, Virginia; Stockbridge, Massachusetts; and at Halifax, in British America. Another was witnessed in the autumn of 1818, in the North Sea, when, in the language of the observers, "all the surrounding atmosphere was enveloped in one expansive sea of fire, exhibiting the appearance of another Moscow, in flames."

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* *After the first edition of this work went to press, the author was politely furnished, by Professor Olmsted, with the following communication.*

"I am happy to hear that you propose to stereotype your 'Geography of the Heavens.' It has done much, I believe, to diffuse a popular knowledge of astronomy, and I am pleased that your efforts are rewarded by an extended patronage.

"Were I now to express my views on the subject (*Meteoric Showers*) in as condensed a form as possible, I should state them in some such terms as the following: The meteoric showers which have occurred for several years past on or about the 13th of November, are characterized by four peculiarities, which distinguish them from ordinary shooting stars. First, they are far more numerous than common, and are larger and brighter. Secondly, they are in much greater proportion than usual, accompanied by luminous trains. Thirdly, they mostly appear to radiate from a common center; that is, were their paths in the heavens traced backward, they would meet in the same part of the heavens: this point has for three years past, at least, been situated in the constellation Leo. Fourthly, the greatest display is everywhere at nearly the same time of night, namely, from three to four o'clock—a time about half-way from midnight to sunrise. The meteors are inferred to consist of *combustible* matter, because they are seen to take fire and burn in the atmosphere. They are known to be very light, because, although they fall toward the earth with immense velocity, few, if any, ever reach the earth, but are arrested by the air, like a wad fired from a piece of artillery. Some of them are inferred to be bodies of comparatively *great size*, amounting in diameter to several hundred feet, at least, because they are seen under so large an angle, while they are at a great distance from the spectator. Innumerable small bodies, thus consisting of extremely light, thin, combustible matter, existing together in space far beyond the limits of the atmosphere, are believed to compose a body of immense extent, which has been called 'the nebulous body.' Only the *skirts* or extreme portions of this are brought down to the earth, while the entire extent occupies many thousands, and perhaps several millions of miles. This nebulous body is inferred to have a revolution around the sun, as well as the earth, and to come very near to the latter about the 13th of November each year. This annual meeting every year, for several years in succession, could not take place unless the periodic time of the nebulous body is either nearly a year, or half a year. Various reasons have induced the belief that half a year is the true period; but this point is considered somewhat doubtful. The *zodiacal* light, a faint light that appears at different seasons of the year, either immediately preceding the morning or following the evening twilight, ascending from the sun in a triangular form, is, with some degree of probability, thought to be the nebular body itself, although the existence of such a body, revolving in the solar system, was inferred to be the cause of the meteoric showers, before any connection of it with the zodiacal light was even thought of."

With what remarkable fact does his theory accord? Substance of letter from Professor Olmsted?

306. Exactly *one year previous* to the great phenomenon of 1833, namely, on the 12th of November, 1832, a similar meteoric display was seen near *Mocha*, on the *Red Sea*, by Capt. Hammond and crew of the ship Restitution.

A gentleman in *South Carolina* thus describes the effect of the phenomenon of 1833, upon his ignorant blacks: "I was suddenly awakened by the most distressing cries that ever fell on my ears. Shrieks of horror, and cries of mercy, I could hear from most of the negroes of three plantations, amounting in all to about six or eight hundred. While earnestly listening for the cause, I heard a faint noise near the door calling my name; I arose, and taking my sword, stood at the door. At this moment, I heard the same voice still beseeching me to rise, and saying, 'O, my God, the world is on fire!' I then opened the door, and it is difficult to say which excited me most—the awfulness of the scene, or the distressed cries of the negroes; upward of one hundred lay prostrate on the ground—some speechless, and some with the bitterest cries, but most with their hands raised, imploring God to save the world and them. The scene was truly awful; for never did rain fall much thicker, than the meteors fell toward the earth; east, west, north, and south, it was the same!"

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306. What similar meteoric shower referred to? Description of that of November 1833, and its effects upon certain persons?

PART II.

THE SOLAR SYSTEM.

CHAPTER I.

GENERAL PHENOMENA OF THE SOLAR SYSTEM, HISTORY, &c.

307. Our attention has hitherto been directed to those bodies which we see scattered everywhere throughout the whole celestial concave. These bodies, as has been shown, twinkle with a reddish and variable light, and appear to have always the same position with regard to each other. We know that their number is very great, and that their distance from us is immeasurable.

We are also acquainted with their comparative brightness, and their situation. In a word, we have before us their few visible appearances, to which our knowledge of them is well-nigh limited; almost all our reasonings in regard to them being founded on *comparatively* few and uncertain analogies. Accordingly, our *chief* business thus far has been to detail their number, to describe their brightness and positions, and to give the names by which they have been designated.

308. There now remain to be considered certain other celestial bodies, all of which, from their remarkable appearance and changes, and some of them from their intimate connection with the comfort, convenience, and even existence of man, must have always attracted especial observation, and been objects of the most intense contemplation and the deepest interest. Most of these bodies are situated within the limits of the Zodiac. The most important of them are, the Sun, so superior to all the heavenly bodies for its apparent magnitude, for the light and heat which it imparts, for the marked effects of its changes of position with regard to the Earth; and the Moon, so conspicuous among the bodies which give light by night, and from her

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307. Subject of Part II.? Of our investigations hitherto? How distinguished? Their number, distance, &c.? What has been our chief business thus far? 308. What now remains to be considered? How situated? Which the most important of them?

soft and silvery brightness, so pleasing to behold; remarkable not only for changes of position, but for the varied phases or appearances which she presents, as she waxes from her crescent form through all her different stages of increase to a full orb, and wanes back again to her former diminished figure.

309. The partial or total obscuration of these two bodies, which sometimes occurs, darkness taking place even at mid-day, and the face of night, before lighted up by the Moon's beams, being suddenly shaded by their absence, have always been among the most striking astronomical phenomena, and so powerful in their influence upon the beholders, as to fill them with perplexity and fear.

310. If we observe these two bodies, we shall find that, besides their apparent diurnal motion, across the heavens, they exhibit other phenomena, which must be the effect of motion. The Sun during one part of the year will be seen to rise every day farther and farther toward the north, to continue longer and longer above the horizon, to be more and more elevated at mid-day, until he arrives at a certain limit; and then, during the other part, the order is entirely reversed.

311. Again; if the Sun's motions be attentively observed, he will be found to have another motion, opposite to his apparent diurnal motion from east to west. This may be perceived distinctly, if we notice, on any clear evening, any bright star which is first visible after sunset, near the place where he sunk below the horizon. The following evening, the star will not be visible on account of the approach of the Sun, and all the stars on the east of it will be successively eclipsed by his rays, until he shall have made a complete apparent revolution in the heavens. These are the most obvious phenomena exhibited by these two bodies.

312. The Moon sometimes is not seen at all; and then, when she first becomes visible, appears in the west, not far from the setting Sun, with a slender crescent form; every night she appears at a greater distance from the setting Sun, increasing in size, until at length she is found in the east, just as the Sun is sinking below the horizon in the west.

313. There are also situated within the limits of the Zodiac certain other bodies, which, at first view and on a superficial examination, are scarcely distinguishable from the fixed stars.

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309. What said of their obscuration? 310. Of their motions? 311. Has the Sun an apparent eastward motion? 312. What said of the Moon's motions and phases? 313. What other bodies and their motions? What called, and why?

But, observed more attentively, they will be seen to shine with a milder and steadier light, and, besides being carried round with the stars, in the apparent revolution of the great celestial concave, they will seem to change their places in the concave itself. Sometimes they are stationary; sometimes they appear to be moving from west to east, and sometimes to be going back again from east to west; being seen at sunset sometimes in the east, and sometimes in the west, and always apparently changing their position with regard to the earth, each other, and the other heavenly bodies. From their wandering, as it were, in this manner through the heavens, they were called by the Greeks πλανηται, *planets*, which signifies *wanderers*.

314. There also sometimes appear in the heavens, bodies of a very extraordinary aspect, which continue visible for a considerable period, and then disappear from our view; and nothing more is seen of them, it may be, for years, when they again present themselves, and take their place among the bodies of the celestial sphere. They are distinguished from the planets by a dull and cloudy appearance, and by a train of light. As they approach the sun, however, their faint and nebulous light becomes more and more brilliant, and their train increases in length until they arrive at their nearest point of approximation, when they shine with their greatest brilliancy. As they recede from the Sun, they gradually lose their splendor, resume their faint and nebulous appearance, and their train diminishes, until they entirely disappear. They have no well-defined figure; they seem to move in every possible direction, and are found in every part of the heavens. From their train they were called by the Greeks κομηται, *comets*, which signifies *bearded*, or *having long hair*.

The causes of these various phenomena must have early constituted a very natural subject of inquiry. Accordingly, we shall find, if we examine the history of the science, that in very early times there were many speculations upon this subject, and that different theories were adopted to account for these celestial appearances.

315. The Egyptians, Chaldeans, Indians, and Chinese, early possessed many astronomical facts, many observations of important phenomena, and many rules and methods of astronomical calculation; and it has been supposed, that they had the ruins of a great system of astronomical science, which in the earliest ages of the world had been carried to a great degree of perfection, and that while the principles and explanations of the phe-

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314. Any other bodies described? How distinguished? What called, and why? Is it probable that these phenomena were early observed? 315. What said of the Egyptians, Chaldeans, &c.? Of the Chinese in particular? Of the Indians and Chaldeans?

nomena were lost, the isolated, unconnected facts, rules of calculation, and phenomena themselves, remained.

Thus, the Chinese, who, it is generally agreed, possess the oldest authentic observations on record, have recorded in their annals, a conjunction of five planets at the same time, which happened 2461 years before Christ, or 100 years before the flood. By mathematical calculation, it is ascertained that this conjunction really occurred at that time. The first observation of a solar eclipse of which the world has any knowledge, was made by the Chinese, 2128 years before Christ, or 220 years after the deluge. It seems, also, that the Chinese understood the method of calculating eclipses; for, it is said, that the emperor was so irritated against the great officers of state for neglecting to predict the eclipse, that he caused them to be put to death. The Chinese have, from time immemorial, considered Solar Eclipses and conjunctions of the planets, as prognostics of importance to the Empire, and they have been predicted as a matter of state policy.

The astronomical epoch of the Chinese, according to Bailly, commenced with Fohi, their first emperor, who flourished 2952 years before the Christian era, or about 350 years before the deluge. If it be asked how the knowledge of this antediluvian astronomy was preserved and transmitted, it is said that the columns on which it was registered have survived the deluge, and that those of Egypt are only copies which have become originals, now that the others have been forgotten. The Indians, also, profess to have many celestial observations of a very early date. The Chaldeans have been justly celebrated in all ages for their astronomical observations. When Alexander took Babylon, his preceptor, Callisthenes, found a series of Chaldean observations, made in that city, and extending back, with little interruption, through a period of 1903 years preceding that event. This would carry us back to at least 2234 years before the birth of Christ, or to about the time of the dispersion of mankind by the confusion of tongues.

316. The Greeks, in all probability, derived many notions in regard to this science, and many facts and observations, from Egypt, the great fountain of ancient learning and wisdom, and many were the speculations and hypotheses of their philosophers. The first of the Greek philosophers who taught Astronomy was Thales, of Miletus. He flourished about 640 years before the Christian era. Then followed Anaximander, Anaximenes, Anaxagoras, Pythagoras, Plato.

Some of the doctrines maintained by these philosophers were, that the Earth was round, that it had two motions, a diurnal motion on its axis, and an annual motion around the Sun, that the Sun was a globe of fire, that the Moon received her light from the Sun, that she was habitable, contained mountains, seas, &c.: that her eclipses were caused by the Earth's shadow, that the planets were not designed merely to adorn our heavens, that they were worlds of themselves, and that the fixed stars were centers of distant systems. Some of them, however, maintained that the Earth was flat, and others that, though round, it was at rest in the center of the universe.

317. When that distinguished school of philosophy was established at Alexandria, in Egypt, by the munificence of the sovereigns to whom that portion of Alexander's empire had fallen, astronomy recived a new impulse. It was now, in the second century after Christ, that the first complete system or treatise of astronomy of which we have any knowledge, was formed. All before had been unconnected and incomplete. Ptolemy, with the opinions of all antiquity, and of all the philosophers

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316. Of the Greeks? Who first taught astronomy among them? Date? Who next? State some of their doctrines? 317. What record of this science? What of Ptolemy and his works?

who had preceded him, spread out before him, composed a work in thirteen books, called the Μεγαλη Συνταξις, or Great System.

318. Rejecting the doctrine of Pythagoras, who taught that the Sun was the center of the universe, and that the Earth had a diurnal motion on its axis and an annual motion around the Sun, as contrary to the evidence of the senses, Ptolemy endeavored to account for the celestial phenomena, by supposing the Earth to be the center of the universe, and all the heavenly bodies to revolve around it.

He seems to have entertained an idea, in regard to the supposition, that the Earth revolved on its axis, similar to one which some entertain even at the present day. "If," says he, "there were any motion of the Earth common to it and all other heavenly bodies, it would certainly precede them all by the excess of its mass being so great; and animals and a certain portion of heavy bodies would be left behind, riding upon the air, and the earth itself would very soon be completely carried out of the heavens."

319. In explaining the celestial phenomena, however, upon his hypothesis, he met with a difficulty in the apparently stationary attitude and retrograde motions which he saw the planets sometimes have. To explain this, however, he supposed the planets to revolve in small circles, which he called epicycles, which were, at the same time, carried around the Earth in larger circles, which he called deferents, or carrying circles.

In following out his theory, and applying it to the explanation of different phenomena, it became necessary to add new epicycles, and to have recourse to other expedients, until the system became unwieldy, cumbrous, and complicated. This theory, although astronomical observations continued to be made, and some distinguished astronomers appeared from time to time, was the prevailing theory until the middle of the 15th century. It was not, however, *always* received with implicit confidence; nor were its difficulties *always* entirely unappreciated.

Alphonso X., king of Castile, who flourished in the 13th century, when contemplating the doctrine of the epicycles, exclaimed, "Were the universe thus constructed, if the Deity had called me to his councils at the creation of the world, I could have given him good advice." He did not, however, mean any impiety or irreverence, except what was directed against the system of Ptolemy.

320. About the middle of the 15th century, Copernicus, a native of Thorn in Prussia, conceiving a passionate attachment to the study of astronomy, quitted the profession of medicine, and devoted himself with the most intense ardor to the study of this science. "His mind," it is said, "had long been imbued with the idea that simplicity and harmony should characterize the arrangements of the planetary system. In the complication and disorder which he saw reigned in the hypothesis of Ptolemy, he perceived insuperable objections to its being considered as a representation of nature."

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318. His system of astronomy? What singular idea and reasoning? 319. What difficulty did he meet with, and how explain it? What further difficulty? How long did this theory prevail? What anecdote of the King of Castile? 320. What distinguished student of astronomy now arose? His impressions in regard to the Ptolemaic theory? His own earlier convictions? What other theories did he study?

In the opinions of the Egyptian sages, in those of Pythagoras, Philolaus, Aristarchus, and Nicetas, he recognized his own earliest conviction that the Earth was not the center of the universe. His attention was much occupied with the speculation of Martinus Capella, who placed the Sun between Mars and the Moon, and made Mercury and Venus revolve round him as a center, and with the system of Appollonius Pergœus who made all the planets revolve around the Sun, while the Sun and Moon were carried around the Earth in the center of the universe.

321. The examination, however, of various hypotheses, by Copernicus, gradually expelled the difficulties with which the subject was beset, and after the labor of more than thirty years, he was permitted to see the true system of the universe. The Sun he considered as immovable, in the center of the system, while the Earth revolved around him, between the orbits of Venus and Mars, and produced by its rotation about its axis all the diurnal phenomena of the celestial sphere. The other planets he considered as revolving about the Sun, in orbits exterior to that of the Earth. (*See the Relative Distances of the Planets' Orbits, Map I. of the Atlas.*)

Thus, the stations and retrogradations of the planets were the necessary consequence of their own motions, combined with that of the Earth about the Sun. He said that "by long observation, he discovered that, if the motions of the planets be compared with that of the Earth, and be estimated according to the times in which they perform their revolutions, not only their several appearances would follow from this hypothesis, but that it would so connect the order of the planets, their orbits, magnitudes, and distances, and even the apparent motion of the fixed stars, that it would be impossible to remove one of these bodies out of its place without disordering the rest, and even the whole of the universe also."

322. Soon after the death of Copernicus, arose Tycho Brahe, born at Knudstorp, in Norway, in 1546. Such was the distinction which he had attained as an astronomer, that when, dissatisfied with his residence in Denmark, he had resolved to remove, the King of Denmark, learning his intentions, detained him in the kingdom, by presenting him with the canonry of Rothschild, with an income of 2,000 crowns per annum. He added to this sum a pension of 1,000 crowns, gave him the island of Huen, and established for him an observatory at an expense of about 200,000 crowns. Here Tycho continued, for twenty-one years, to enrich astronomy with his observations.

His observations upon the Moon were important, and upon the planets numerous and precise, and have formed the data of the present generalizations in astronomy. He, however, rejected the system of Copernicus; considering the Earth as immovable in the center of the system, while the Sun, with all the planets and comets revolving around him, performed his revolution around the earth, and, in the course of twenty-four hours, the stars also revolved about the central body. This theory was not so simple as that of Copernicus, and involved the absurdity of making the Sun, planets, &c., revolve around a body comparatively insignificant.

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321. How was Copernicus led to discover the true system of astronomy? What is that system? Does it account for the stations and retrogradations of the planets? 322. What distinguished astronomer next arose? What said of his detention in Denmark? His observations? His theory

323. Near the close of the 15th century, arose two men, who wrought most important changes in the science; Kepler and Galileo, the former a German, the latter an Italian. Previous to Kepler, all investigations proceeded upon the supposition that the planets moved in circular orbits which had been a source of much error. This supposition Kepler showed to be false. He discovered that their orbits were ellipses. The orbits of their secondaries or moons he also found to be the same curve. He next determined the dimensions of the orbits of the planets, and found to what their velocities in their motions through their orbits, and the times of their revolutions, were proportioned; all truths of the greatest importance to the science.

324. While Kepler was making these discoveries of facts, very essential for the explanation of many phenomena, Galileo was discovering wonders in the heavens never before seen by the eye of man. Having improved the telescope, and applied it to the heavens, he observed mountains and valleys upon the surface of our Moon; satellites or secondaries were discovered revolving about Jupiter; and Venus, as Copernicus had predicted, was seen exhibiting all the different phases of the Moon, waxing and waning as she does, through various forms.

Many minute stars, not visible to the naked eye, were described in the Milky-Way; and the largest fixed stars, instead of being magnified, appeared to be small brilliant points, an incontrovertible argument in favor of their immense distance from us. All his discoveries served to confirm the Copernican theory, and to show the absurdity of the hypothesis of Ptolemy.

325. Although the general arrangement and motions of the planetary bodies, together with the figure of their orbits, had been thus determined, the force of power which carries them around in their orbits, was as yet unknown. The discovery of this was reserved for the illustrious Newton, though even his discovery was in some respects anticipated by Copernicus, Kepler and Hooke. By reflecting on the nature of gravity—that power which causes bodies to descend toward the center of the earth—since it does not sensibly diminish at the greatest distance from the center of the earth to which we can attain, being as powerful on the loftiest mountains as it is in the deepest caverns, he was led to imagine that it might extend to the Moon, and that it might be the power which kept her in her orbit, and caused her to revolve around the Earth. He was next led to suppose that perhaps the same power carried the

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323. What two noted astronomers next arose? What did Kepler discover? 324. Galileo and his discoveries? What theory did they serve to establish? 325 What great discovery next made, and by whom? How led to it? Successive steps?

primary planets around the Sun. By a series of calculations, he was enabled at length to establish the fact, that the same force which determines the fall of an apple to the Earth, carries the moons in their orbits around the planets, and the planets and comets in their orbits around the Sun.

To recapitulate briefly: The system (not hypothesis, for much of it has been established by mathematical demonstration) by which we are now enabled to explain with a beautiful simplicity the different phenomena of the Sun, planets, moons, and comets, is, that the Sun is the central body in the system: that the planets and comets move round him in elliptical orbits, whose planes are more or less inclined to each other, with velocities bearing to each other a certain ascertained relation, and in times related to their distances; that the moons, or secondaries, revolve in like manner about their primaries, and at the same time accompany them in their motion around the Sun; all meanwhile revolving on axes of their own; and that these revolutions in their orbits are produced by the mysterious power of attraction. The particular mode in which this system is applied to the explanation of the different phenomena, will be exhibited as we proceed to consider, one by one, the several bodies above mentioned.

326. These bodies, thus arranged and thus revolving, constitute what is termed the Solar System. The planets have been divided into two classes, primaries and secondaries. The latter are also termed moons, and sometimes satellites. The primaries are those that revolve about the Sun, as a center. The secondaries are those which revolve about the primaries. There have been discovered to this date (1854), thirty-five primary planets, viz.: Mercury, Venus, the Earth, Mars, Flora, Clio, Vesta, Iris, Metis, Eunomia, Psyche, Thetis, Melpomene, Fortuna, Massilia, Lutetia, Calliope, Thalia, Hebe, Parthenope, Irene, Egeria, Astræa, Juno, Ceres, Pallas, Hygeia, Jupiter, Saturn, Uranus, Neptune, and four other Asteroids, whose names and places have not yet been determined. Mercury is the nearest to the Sun, and the others follow in the order in which they are named. The seventeen small planets from Flora to Hygeia, inclusive, were discovered by means of the telescope, and, because they are very small, compared with the others, are called Asteroids. Neptune, also, is a telescopic planet, though much larger than any of the Asteroids.

There have been discovered twenty secondaries. Of these, the Earth has one, Jupiter four, Saturn eight, Herschel six, and Neptune one All these, except our Moon, as well as the Asteroids and Neptune, are invisible to the naked eye.

Map I. of the Atlas, "exhibits a plan of the Solar System," comprising the relative magnitudes of the Sun and Planets; their comparative distances from the Sun, and from each other; the position of their orbits, with respect to each other; the Earth and the Sun; together with many other particulars which are explained on the map. There, the

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Describe the Copernican theory? 326. What do the bodies mentioned constitute? How are the planets divided? Describe each? What number of primaries? Name them in order from the Sun? Which are the Asteroids? Which telescopic? How many secondary planets? How distributed? Are they visible to the naked eye? What said first and most prominent object which claims attention, is the representation of the Sun's circumference, with its deep radiations, bounding the upper margin of the map. It is apparent, however, that this segment is hardly *one-sixth* of the whole circumference of which it is a part. Were the map sufficiently large to admit the entire orb of the Sun, even upon so diminutive a scale as there represented, we should then see the Sun and Planets in their just proportions—the diameter of the former being 112 times the diameter of the Earth.

It was intended, originally, to represent the Earth upon a scale of *one inch* in diameter and the other bodies in that proportion; but it was found that it would increase the map to four times its size; and hence it became necessary to assume a scale of *half* an inch for the Earth's diameter, which makes that of the Sun 56 inches, and the other bodies, as represented upon the map.

The relative position of the Planets' orbits is also represented, on a scale as large as the sheet would permit. Their relative distances from the Sun as a center, and from each other, are there shown correctly. But had we wished to enlarge the dimensions of these orbits, so that they would exactly correspond with the scale to which we have drawn the planets, the map must have been nearly two miles in length. "Hence," says Sir John Herschel, "the idea that we can convey correct notions on this subject, by drawing circles on paper, is out of the question."

To illustrate this—Let us suppose ourselves standing on an extended plane, or field of ice, and that a globe 4 feet 8 inches in diameter is placed in the center of the plane, to represent the Sun. Having cut out of the map the dark circles representing the planets, we may proceed to arrange them in their respective orbits about the Sun, as follows:

First, we should take Mercury, about the size of a small currant, and place it on the circumference of a circle 194 feet from the Sun; this circle would represent the orbit of Mercury, in the proper ratio of its magnitude. Next, we should take Venus, about the size of a rather small cherry, and place it on a circle 362 feet from the Sun, to represent the orbit of Venus. Then would come the Earth, about the size of a cherry, revolving in an orbit 500 feet from the Sun. After the Earth we should place Mars, about the size of a cranberry, on a circle 762 feet from the Sun. Neglecting the Asteroids, some of which would not be larger than a pin's head, we should place Jupiter, hardly equal to a moderate-sized melon, on a circle at the distance of half a mile (2601 feet) from the Sun; Saturn, somewhat less, on a circle nearly a mile (4768 feet) from the Sun; Herschel, about the size of a peach, on the circumference of a circle nearly 2 miles (9591 feet) from the Sun; and last of all Neptune, a little larger than Herschel, and on a circle of nearly 3 miles (15,366 feet) from the Sun.

To imitate the motions of the planets in the above-mentioned orbits, Mercury must describe its own diameter in 41 seconds; Venus, in 4 minutes 14 seconds; the Earth, in 7 minutes; Mars, in 4 minutes 48 seconds; Jupiter, in 2 hours 56 minutes; Saturn, in 3 hours 13 minutes; Herschel, in 12 hours 16 minutes; and Neptune, in 23 hours 25 min.

Many other interesting subjects are embraced in Map I.; but they are either explained on the map, or in the following chapters, to which they respectively relate.

CHAPTER II.

THE SUN—HIS DISTANCE, MAGNITUDE, &c.

327. THE Sun is a vast globe, in the center of the solar system, dispensing light and heat to all the planets, and governing all their motions. It is the great parent of vegetable life, giving warmth to the seasons, and color to the landscape. Its rays are the cause of various phenomena on the surface of the earth and in the atmosphere. By their agency, all winds are pro-

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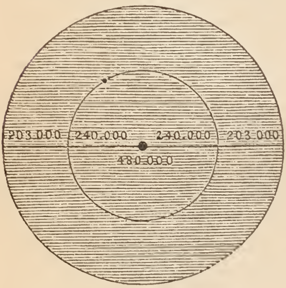
of Map I.? Its scale? Remark of Dr. Herschel? What illustrations of the Solar System does he furnish? 327. Subject of Chapter II.? Describe the Sun?

duced, and the waters of the sea are made to circulate in vapor through the air, and irrigate the land, producing springs and rivers.

328. The Sun is by far the largest of the heavenly bodies whose dimensions have been definitely ascertained. Its diameter is about 886,000 miles. Consequently, it contains a volume of matter equal to *fourteen hundred thousand globes* of the size of the Earth. Of a body so vast in its dimensions, the human mind, with all its efforts, can form no adequate conception

THE SUN AND THE MOON'S ORBIT.



Were the Sun a hollow sphere, perforated with a thousand openings to admit the twinkling of the luminous atmosphere around it—and were a globe as large as the Earth placed at its center, with a satellite as large as our Moon, and at the same distance from it as she is from the earth, there would be present to the eye of a spectator on the interior globe, a universe as splendid as that which now appears to the uninstructed eye—a universe as large and extensive as the whole creation was conceived to be in the infancy of astronomy.

The mean distance of the Moon from the Earth is 240,000 miles, consequently the average diameter of her orbit is 480,000 miles; and yet, were the Sun to take the place of the Earth, he would fill the whole orbit of the Moon, and extend 200,000 miles beyond it in every direction! To pass from side to side through his center, at railroad speed (30 miles an hour), would require nearly three and a half years, and to traverse his vast circumference nearly eleven years.

Here let the student refer to Map I., where the Relative Magnitudes of the Sun and Planets are exhibited. Let him compare the segment of the Sun's circumference, as there represented, with the entire circumference of the Earth. They are both drawn upon the same scale. The segment of the Sun's circumference, since it is almost a straight line, must be a very small part of what the whole circumference would be, were it represented entire. Let the student understand this diagram, and he will be in some measure able to conceive how like a mere point the Earth is, compared with the Sun, and to form in his mind some image of the vast magnitude of the latter.

329. The next thing which fills the mind with wonder, is the *distance* at which so great a body must be placed, to occupy, apparently, so small a space in the firmament. The Sun's mean distance from the Earth is twelve thousand times the Earth's diameter, or a little more than 95,000,000 of miles. We may derive some faint conception of such a distance, by considering that the swiftest steamboats, which ply our waters at the rate of 200 miles a day, would not traverse it in *thirteen hundred years;* and, that a cannon ball, flying night and day, at the rate of 16 miles a minute, would not reach it in *eleven years.*

330. The Sun, when viewed through a telescope, presents the appearance of an enormous globe of fire, frequently in a state of violent agitation or ebullition; dark spots of irregular form,

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328. His magnitude? Diameter? Compared with the Earth? What illustration given? What reference to the Map? 329. Distance of the Sun? What illustration given? 330. How does the Sun appear through a telescope? Describe these spots?

rarely visible to the naked eye, frequently pass over his disc, from east to west, in the period of nearly fourteen days.

SPOTS ON THE SUN.

These spots are usually surrounded by a penumbra, or less deeply shaded border, and that, by a margin of light more brilliant that that of the Sun. A spot when first seen on the eastern edge of the Sun, appears like a line which progressively extends in breadth, and increases its apparent velocity, till it reaches the middle, when it begins to contract, and to move less rapidly, till it ultimately disappears at the western edge. In some rare instances, the same spots re-appear on the east side, and are permanent for two or three revolutions. But, as a general thing, the spots on the Sun are neither permanent nor uniform. Sometimes several small ones unite into a large one; and, again, a large one separates into numerous small ones. Some continue several days, weeks, and even months, together; while others appear and disappear, in the course of a few hours. Those spots that are formed gradually, are, for the most part, as gradually dissolved; whilst those that are suddenly formed, generally vanish as quickly.

331. It is the general opinion, that spots on the Sun were first discovered by Galileo, in the beginning of the year 1611; though Scheiner, Harriot, and Fabricius, observed them about the same time. During a period of 18 years from this time, the Sun was never found entirely clear of spots, excepting a few days in December, 1624: at other times, there were frequently seen twenty or thirty at a time, and in 1625, upwards of fifty were seen at once. From 1650 to 1670, scarcely any spots were to be seen; and, from 1676 to 1684, the orb of the Sun presented an unspotted disc. Since the beginning of the eighteenth century, scarcely a year has passed, in which spots have not been visible, and frequently in great numbers. In 1799, Dr Herschel observed one nearly 30,000 miles in breadth.

A single second of angular measure, on the Sun's disc, as seen from the Earth, corresponds to 462 miles; and a circle of this diameter (containing therefore nearly 220,000 square miles) is the least space which can be distinctly discerned on the Sun as a *visible area*, even by the most powerful glasses. Spots have been observed, however, whose linear diameter has been more than 44,000 miles; and, if some records are to be trusted, of even still greater extent.

Dr. Dick, in a letter to the author, says: "I have for many years examined the solar spots with considerable minuteness, and have several times seen spots which were not less than the one twenty-fifth part of the Sun's diameter, which would make them about 22,192 miles in diameter, yet they were visible neither to the naked eye, nor through an opera glass magnifying about three times. And, therefore, if any spots have been visible to the naked eye—which we must believe, unless we refuse respectable testimony—they could not have been much less than 50,000 miles in diameter."

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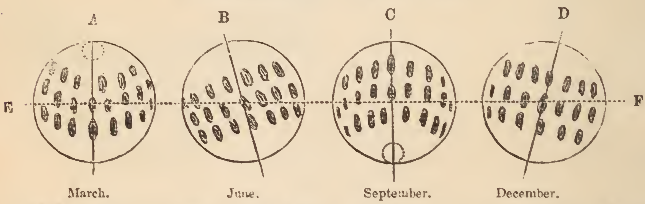
331. Who first saw them? When? How was it for the next 18 years? How in 1625? From 1650 to 1670? From 1676 to 1684? How since the beginning of the eighteenth century? Dr. Herschel's measurements? Dr. Dick's remarks and conclusion?

332. The apparent direction of these spots over the Sun's disc is continually varying. Sometimes they seem to move across it in *straight* lines, at others in *curve* lines. Sometimes the spots seem to move *upward*, as they cross from east to west, while at other times they incline *downward*, while the curve lines are sometimes convex towards one pole of the Sun, and sometimes towards the other.

333. All these phenomena are owing to the fact that the axis of the Sun is inclined to the ecliptic, so that viewing him from different points in the Earth's orbit, the apparent direction of the spots must necessarily vary. The following diagrams may serve to illustrate :

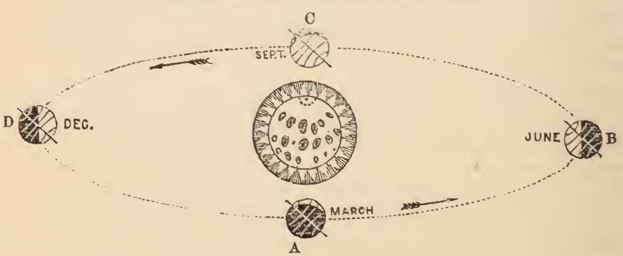
VARIOUS DIRECTIONS OF THE SOLAR SPOTS.



Let E F represent the plane of the ecliptic. In March, the spots describe a curve, which is convex to the south, as shown at A. In June, they cross the Sun's disc in nearly straight lines, but incline upward. In September, they curve again, though in the opposite direction ; and in December, pass over in straight lines, inclining *downward*. The figures B and D show the inclination of the Sun's axis.

The following diagram will serve still further to illustrate the cause of the change of direction of the solar spots.

SOLAR SPOTS OBSERVED FROM DIFFERENT POINTS.



Let the student imagine himself stationed upon the earth at A, in March, looking upon the sun in the center, whose north or upper pole is now inclined *toward him*. The spots will then *curve downward*. Three months afterward—viz., in June—the earth will be

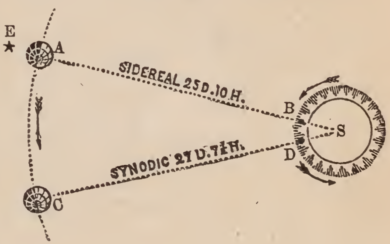
332. In what *general* direction do these spots move? What variations? 333. What is the *cause* of these varying phenomena?

at B; when the sun's axis will incline *to the left*, and the spots seem to pass *upward* to the right. In three months longer, the observer will be at C, when the north pole of the sun will incline *from him*, and the spots seem to *curve upward;* and in three months longer, he will be at D, when the axis of the sun will incline *to the right*, and the spots seem to incline downward.

334. From the regularity with which these spots revolve, it is concluded, with good reason, that they adhere to the surface of the Sun and revolve with it. They are all found within 30° of his equator, or within a zone 60 in width.

335. The apparent revolution of a spot, from any particular point of the Sun's disc, to the same point again, is accomplished in 27 days, 7 hours, 26 minutes, and 24 seconds; but during that time, the spot has, in fact, gone through one revolution, together with an arc, equal to that described by the Earth in her orbit in the same time; which reducest he time of the Sun's actual rotation on his axis, to 25 days, 9 hours, and 36 minutes.

SIDEREAL AND SYNODIC REVOLUTIONS OF THE SUN.



Let S represent the sun, and A the earth in her orbit. When she is at A, a spot is seen upon the disc of the sun at B. The sun revolves in the direction of the arrows, and in 25 days 10 hours the spot comes round to B again, or opposite the star E. This is a *sidereal* revolution.

During these 25 days 8 hours, the earth has passed on in her orbit some 25°, or nearly, to C, which will require nearly two days for the spot at B to get directly toward the earth, as shown at D. This last is a *synodic* revolution. It consists of one complete revolution of the sun upon his axis, and about 27° over.

336. The part of the Sun's disc not occupied by spots, is far from being uniformly bright. Its *ground* is finely mottled with an appearance of minute dark dots, or *pores*, which, attentively watched for several days in succession, are found to be in a constant state of change.

What the physical organization of the Sun may be, is a question which astronomy, in its present state, cannot solve. It seems, however, to be surrounded by an ocean of inexhaustible flame, with dark spots of enormous size, now and then floating upon its surface. From these phenomena, Sir W. Herschel supposed the Sun to be a solid, dark body, surrounded by a vast

334. Are these spots supposed to adhere to the body of the Sun? On what part of the Sun are they found? 335. What is their time of *apparent* revolution? The *actual* time? How arrived at? 336. What said of the part of the Sun about his poles? Of his physical organization? What does it seem to be? How did Sir W. Herschel regard it?

atmosphere, almost always filled with luminous clouds, occasionally opening and disclosing the dark mass within.

337. The speculations of Laplace were different. He imagined the solar orb to be a mass of fire, and the violent effervescences and explosions seen on its surface, to be occasioned by the eruption of elastic fluids, formed in its interior, and the spots to be enormous caverns, like the craters of our volcanoes. Others have conjectured that these spots are the tops of solar mountains, which are sometimes left uncovered by the luminous fluid in which they are immersed.

338. Among all the conflicting theories that have been advanced, respecting the physical constitution of the Sun, there is none entirely free from objection. The *prevailing* one seems to be, that the lucid matter of the Sun is neither a liquid substance, nor an elastic fluid, but that it consists of luminous clouds, floating in the Sun's atmosphere, which extends to a great distance, and that these dark spots are the opaque body of the Sun, seen through the openings in his atmosphere. Herschel supposes that the density of the luminous clouds need not be greater than that of our Aurora Borealis, to produce the effects with which we are acquainted.

339. The similarity of the Sun to the other globes of the system, in its supposed solidity, atmosphere, surface diversified with mountains and valleys, and rotation upon its axis, has led to the conjecture that it is inhabited, like the planets, by beings whose organs are adapted to their peculiar circumstances. Such was the opinion of the late Dr. Herschel, who observed it unremittingly, with the most powerful telescopes, for a period of fifteen years. Such, too, was the opinion of Dr. Elliot, who attributes to it the most delightful scenery ; and, as the light of the Sun is eternal, so, he imagined, were its seasons. Hence he infers that this luminary offers one of the most blissful habitations for intelligent beings of which we can conceive.

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337. Laplace's speculations? What other opinions? 338. Is there a satisfactory theory of the physical nature of the Sun? State the prevailing one? Herschel's supposition? 339. What conjecture in regard to the inhabitants of the Sun, and upon what founded? Who held to this idea?

CHAPTER III.

THE PRIMARY PLANETS—MERCURY AND VENUS.

340. Mercury is the nearest planet to the Sun that has yet been discovered, and with the exception of the asteroids, is the smallest. Its diameter is only 3,140 miles. Its bulk, therefore, is about sixteen times less than that of the Earth. It would require more than twenty millions of such globes to compose a body equal to the Sun.

Here the student should refer to the diagrams, exhibiting the relative magnitudes and distances of the Sun and Planets, Map I. And whenever this subject recurs in the course of this work, the student should recur to the figures of this Map, until he is able to form in his mind distinct conceptions of the relative magnitudes and distances of all the planets. The Sun and planets being spheres, or nearly so, their relative bulks are estimated by comparing the cubes of their diameters: thus, the diameter of Mercury being 3,140 miles, and that of the Earth 7,912; their bulks are as the cube of 3,140, to the cube of 7,912, or as 1 to 16, nearly.

341. Mercury revolves on its axis from west to east in 24 hours, 5 minutes, and 28 seconds; which makes its day about 10 minutes longer than ours. It performs its revolution about the Sun in a few minutes less than 88 days, and at a mean distance of nearly 37,000,000 of miles. The length of Mercury's year, therefore, is equal to about three of our months.

The rotation of a planet on its axis, constitutes its day; its revolution about the Sun constitutes its year.

342. Owing to the dazzling brightness of Mercury, the swiftness of its motion, and its nearness to the Sun, astronomers have made but comparatively few discoveries respecting it. When viewed through a telescope of considerable magnifying power, it exhibits at different periods all the various phases of the Moon; except that it never appears quite full, because its enlightened hemisphere is never turned directly towards the Earth, only when it is *behind* the Sun, or so near to it as to be hidden by the splendor of its beams. Its enlightened hemisphere being thus always turned towards the Sun, and the opposite one being always dark, prove that it is an opaque body, similar to the Earth, shining only in the light which it receives from the Sun.

343. Mercury is not only the most dense of all the planets, but receives from the Sun six and a half times as much light and

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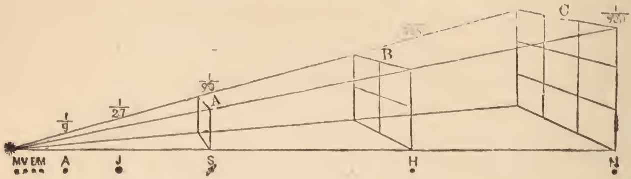
340. Subject of Chapter III.? Size and position of Mercury? What map illustrates this subject? 341. State the time of Mercury's revolution upon his axis? How does this compare with the Earth? His period of revolution around the Sun? 342. What said of discoveries upon Mercury, his phases, &c.? What proof that he is opaque?

heat as the Earth. The truth of this estimate, of course, depends upon the supposition that the intensity of solar light and heat at the planets, varies inversely as the squares of their distances from the Sun.

PHILOSOPHY OF THE DIFFUSION OF LIGHT.



In this diagram the light is seen passing in right lines, from the sun on the left toward the several planets on the right. It is also shown that the surfaces A, B, and C receive equal quantities of light, though B is four times, and C nine times as large as A; and as the light falling upon A is spread over four times as much surface at B, and nine times as much at C, it follows that it is only one-ninth as intense at C, and one-fourth at B, as it is at A. Hence the rule, that *the light and heat of the planet is, inversely, as the squares of their respective distances.*

The student may not exactly understand this last statement. The square of any number is its product, when multiplied by itself. Now suppose we call the distances A, B, and C, 1, 2, and 3 miles. Then the square of 1 is 1; the square of 2 is 4; and the square of 3 is 9. The light and heat, then, would be in *inverse* proportion at these three points, as 1, 4, and 9; that is, four times less at B than at A, and nine times less at C. These amounts we should state as 1, ¼, and one-ninth.

344. This law of analogy, did it exist with rigorous identity at all the planets, would be no argument against their being inhabited; because we are bound to presume that the All-wise Creator has attempered every dwelling-place in his empire to the physical constitution of the beings which he has placed in it.

From a variety of facts which have been observed in relation to the production of *caloric*, it does not appear probable, that the degree of heat on the surface of the different planets depends on their respective distances from the Sun. It is more probable, that it depends chiefly on the distribution of the *substance of caloric* on the surfaces, and throughout the atmospheres of these bodies, in different quantities, according to the different situations which they occupy in the solar system; and that these different quantities of caloric are put into action by the influence of the solar rays, so as to produce that degree of *sensible* heat requisite to the wants, and to the greatest benefit of each of the planets. On this hypothesis, which is corroborated by a great variety of facts and experiments, there may be no more sensible heat experienced on the planet Mercury, than on the surface of Herschel, which is fifty times farther removed from the Sun.

345. The rotation of Mercury on its axis, was determined from the daily position of its horns, by M. Schroeter, who not only discovered spots upon its surface, but several mountains in its southern hemisphere, one of which was 10¾ miles high—nearly three times as high as Chimborazo, in South America.

343. His density, and light and heat? Upon what rule is this estimate based? 344. Would not this law of analogy make against the doctrine that the planets are inhabited? Is it probable that this law does prevail? Upon what may the relative heat of the planets depend? 345. How was his diurnal revolution determined, and by whom? What said of his surface? What observation respecting mountains in general?

It is worthy of observation, that the highest mountains which have been discovered in Mercury, Venus, the Moon, and perhaps we may add the Earth, are all situated in their southern hemispheres.

346. During a few days in March and April, August and September, Mercury may be seen for several minutes, in the morning or evening twilight, when its greatest elongations happen in those months; in all other parts of its orbit, it is too near the Sun to be seen by the naked eye. The greatest distance that it ever departs from the Sun, on either side, varies from 16° 12′, to 28° 48′, *alternately*.

The distance of a planet from the Sun, as seen from the Earth (measured in degrees), is called its elongation. The greatest *absolute* distance of a planet from the Sun is denominated its *aphelion*, and the least its *perihelion*.

347. The revolution of Mercury about the Sun, like that of all the planets, is performed from west to east, in an orbit which is nearly circular. Its *apparent* motion, as seen from the Earth, is, alternately, from west to east, and from east to west, nearly in straight lines; sometimes directly across the disc of the Sun, but at all other times either a little above or a little below it.

Were the orbits of Mercury and Venus in the same plane with that of the Earth, they would cross the Sun's disc at every revolution; but as one-half of each of their orbits is *above*, and the other half *below* the ecliptic, they generally appear to pass either above or below the Sun.

Let the right line A, joining the Earth and the Sun in the above diagram, represent the plane of the ecliptic. Now when an interior planet is in this plane, as shown at A, it may appear to be upon the Sun's disc; but if it is either above or below the ecliptic, as shown at B and C, it will appear to pass either above or below the Sun, as shown at D and E.

For the relative position of the planets' orbits, and their inclination to the plane of the ecliptic, see I, of the Atlas. Here the dotted lines continued from the dark lines, denote the inclination of the orbits to the plane of the ecliptic, which inclination is marked in figures on them. Let the student fancy as many circular pieces of paper intersecting each other at the several angles of inclination marked on the Map, and he will be enabled to understand more easily what is meant by the "inclination of the planets' orbits."

348. Being commonly immersed in the Sun's rays in the evening, and thus continuing invisible till it emerges from them in the morning, Mercury appeared to the ancients like two distinct stars. A long series of observations was requisite, before they

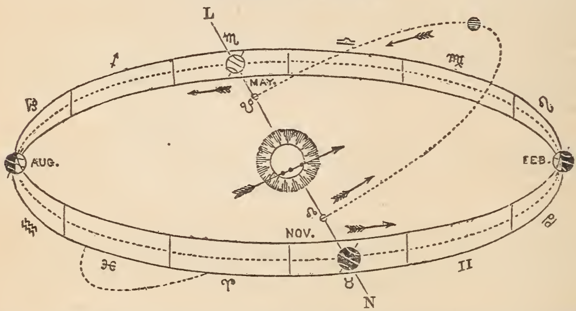
346. When may Mercury be seen? Why not at other times? How far does it depart from the Sun on either side? What is meant by the *elongation* of a planet? Its *aphelion* and *perihelion*? 347. In what *direction* do the planets revolve around the Sun? What is the *apparent* motion of Mercury? Do they ever cross the Sun's disc? Why not at every revolution? 348. How was Mercury regarded by the ancients?

recognized the identity of the star which was seen to recede from the Sun in the morning with that which approached it in the evening. But as the one was never seen until the other disappeared, both were at last found to be the *same* planet, which thus oscillated on each side of the Sun.

349. Mercury's oscillation from west to east, or from east to west, is really accomplished in just half the time of its revolution, which is about 44 days ; but as the Earth, in the mean time, follows the Sun in the same direction, the apparent elongations will be prolonged to between 55 and 65 days.

350. The passage of Mercury or Venus directly between the Earth and the Sun, and apparently over his disc, is called a *Transit.* A transit can never occur except when the interior planet is in or very near the ecliptic. The Earth and the planet must be on the same side of the ecliptic ; the planet being at one of its nodes, and the Earth on the line of its nodes.

PHILOSOPHY OF TRANSITS.



This cut represents the ecliptic and zodiac, with the orbit of an interior planet, his nodes, &c. The line of his nodes is, as shown, in the 16° of ♉ and the 16° of ♏. Now if the earth is in ♉, on the line L N, as shown in the cut, when Mercury is at his *ascending node* (☊), he will seem to pass *upward* over the Sun's face, like a dark spot, as represented in the figure. On the other hand, if Mercury is at his *descending node* (☋), when the earth is in the 16° of ♏, the former will seem to pass *downward* across the disc of the Sun.

351. As the nodes of his orbit are on opposite sides of the ecliptic, and are passed by the Earth in May and November, it follows that all transits of Mercury must occur in one or the other of these months. They are, therefore, called the *Node months.* As is shown in the diagram, the Earth passes the

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349. In what time is the oscillation of Mercury from east to west really accomplished? What is the *apparent* time, and why? 350. What is a *transit?* When do they occur? What are the *nodes* of a planet's orbit? The *line* of the nodes? 351. What are the

ascending Node of Mercury in November, and the descending in May; the former of which is in the 16th degree of Taurus, and the latter in the 16th degree of Scorpio.

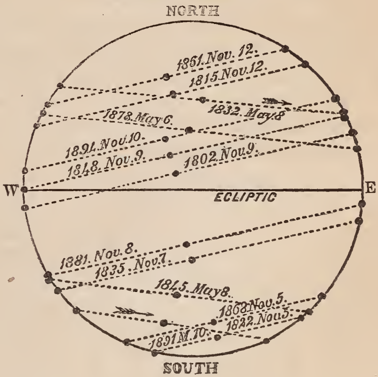
All the transits of Mercury ever noticed have occurred in one or the other of these months, and for the reason already assigned. The first ever observed took place November 6, 1631; since which time there have been 29 others by the same planet—in all 30—8 in May, and 22 in November.

352. The last transit of Mercury occurred November 9, 1848; and the next will take place November 11, 1861. Besides this, there will be five more during the present century—two in May, and three in November.

The accompanying cut is a delineation of all the transits of Mercury from 1802 to the close of the present century. The dark line running east and west across the Sun's center represents the plane of the ecliptic, and the dotted lines the apparent paths of Mercury in the several transits. The planet is shown at its nearest point to the Sun's center. Its path in the last transit and in the next will easily be found.

The last transit of Mercury was observed in this country by Professor Mitchel, at the Cincinnati Observatory, and by many others both in America and in Europe. The editor had made all necessary preparation for observing the phenomenon at his residence, near Oswego, New York; but, unfortunately, his sky was overhung with *clouds*, which hid the sun from his view, and disappointed all his hopes.

TRANSITS OF MERCURY.



353. By comparing the mean motion of any of the planets with the mean motion of the Earth, we may readily determine the periods in which they will return to the same points of their orbit, and the same positions with respect to the Sun. The knowledge of these periods will enable us to determine the hour when the planets rise, set, and pass the meridian, and in general all the phenomena dependent upon the relative position of the Earth, the planet and the Sun; for at the end of one of these periods they commence again, and all recur in the same order.

We have only to find a number of sidereal years, in which the planet completes exactly, or very nearly, a certain number of revolutions; that is, to find such a number of planetary revolutions, as, when taken together, shall be exactly equal to one, or any number of revolutions of the Earth. In the case of Mercury this ratio will be as 87.969 is to 365.256. Whence find that,

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node months of a planet? The node months of Mercury? 352. When did the last transit of Mercury occur? When will the next take place? What others during the present century? What said of the last transit of Mercury? 353. How may we determine when transits will occur? What ratio is found between the revolutions of Mercury

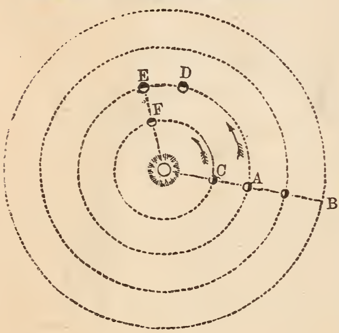
7 periodical revolutions of the Earth are equal to 29 of Mercury:
13 periodical revolutions of the Earth are equal to 54 of Mercury:
33 periodical revolutions of the Earth are equal to 137 of Mercury:
46 periodical revolutions of the Earth are equal to 191 of Mercury.
Therefore, transits of Mercury, at the same node, may happen at intervals of 7, 13, 33, 46, &c. years. Transits of Venus, as well as eclipses of the Sun and Moon, are calculated upon the same principle.

The following is a list of all the Transits of Mercury from the time the first was observed by Gassendi, November 6, 1631, to the end of the present century:

1631 Nov. 6.	1707 May 5.	1776 Nov. 2.	1835 Nov. 7.
1644 Nov. 6.	1710 Nov. 6.	1782 Nov. 12.	1845 May 8.
1651 Nov. 2.	1723 Nov. 9.	1786 May 3.	1848 Nov. 9.
1661 May 3.	1736 Nov. 10.	1789 Nov. 5.	1861 Nov. 11.
1664 Nov. 4.	1740 Nov. 2.	1799 May 7.	1868 Nov. 4.
1674 May 6.	1743 Nov. 4.	1802 Nov. 8.	1878 May 6.
1677 Nov. 7.	1753 May 5.	1815 Nov. 11.	1881 Nov. 7.
1690 Nov. 9.	1756 Nov. 6.	1822 Nov. 4.	1891 May 9.
1697 Nov. 2.	1769 Nov. 9.	1832 May 5.	1894 Nov. 10.

354. The *sidereal* revolution of a planet respects its *absolute* motion; and is measured by the time the planet takes to revolve from any fixed star to the same star again. The *synodical* revolution of a planet respects its *relative* motion; and is measured by the time that a planet occupies in coming back to the same position with respect to the Earth and the Sun.

SIDEREAL AND SYNODIC REVOLUTIONS.



In the adjoining cut the revolution of the Earth from A, opposite the star B, around to the same point again, would be a *sidereal* revolution.

Suppose the Earth and Mercury to start together from the points A C (where Mercury would be in inferior conjunction with the Sun), and to proceed in the direction of the arrows. In 88 days Mercury would come around to the same point again; but as the Earth requires more than four times that number of days for a revolution, she will only have reached the point D when Mercury arrives at C again; so that they will not be in conjunction, and a synodic revolution will not be completed by Mercury. He starts on, however, in *his* second round, and constantly gaining upon the Earth, till in 27 days from the time he left C the second time, he overtakes the Earth at E and F, and is again in inferior conjunction.

From this illustration, it will be seen that the synodic revolution of a planet must always require more time than the sidereal.

355. The *absolute* motion of Mercury in its orbit is 109,757 miles an hour; that of the Earth is 68,288 miles; the difference, 41,469 miles, is the mean *relative* motion of Mercury, with respect to the Earth.

The sidereal revolution of Mercury is 87d. 23h. 15m. 44s. Its *synodical* revolution is

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and the Earth? 354. What is a *sidereal* revolution of a planet? A *synodical?* 355. What is the *absolute* motion of Mercury in his orbit? What is that of the Earth? The difference, or *relative* motion of Mercury? What is his *sidereal* period? His *synodic?* How is the latter ascertained?

found by dividing the whole circumference of 360° by its *relative* motion in respect to the Earth. Thus, the mean daily motion of Mercury is 14732".555; that of the Earth is 3548".318; and their difference is 11184".237, being Mercury's relative motion, or what it gains on the Earth every day. Now by simple proportion, 11184".237 is to 1 day, as 360° is to 115d. 21h. 3', 24", the period of a synodical revolution of Mercury.

VENUS.

356. There are but few persons who have not observed a beautiful star in the west, a little after sunset, call the *evening star*. This star is Venus. It is the second planet from the Sun. It is the brightest star in the firmament, and on this account easily distinguished from the other planets.

If we observe this planet for several days, we shall find that it does not remain constantly at the same distance from the Sun, but that it appears to approach, or recede from him, at the rate of about three-fifths of a degree every day; and that it is sometimes on the east side of him, and sometimes on the west, thus continually oscillating backwards and forwards between certain limits.

357. As Venus never departs quite 48° from the Sun, it is never seen at midnight, nor in opposition to that luminary; being visible only about three hours after sunset, and as long before sunrise, according as its right ascension is greater or less than that of the Sun. At first, we behold it only a few minutes after sunset; the next evening we hardly discover any sensible change in its position; but after a few days, we perceive that it has fallen considerably behind the Sun, and that it continues to depart farther and farther from him, setting later and later every evening, until the distance between it and the Sun is equal to a little more than half the space from the horizon to the zenith, or about 46°. It now begins to return toward the Sun, making the same daily progress that it did in separating from him, and to set earlier and earlier every succeeding evening, until it finally sets with the Sun, and is lost in the splendor of his light.

358. A few days after the phenomena we have now described, we perceive, in the morning, near the eastern horizon, a bright star which was not visible before. This also is Venus, which is now called the *morning star*. It departs farther and farther from the Sun, rising a little earlier every day, until it is seen

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356. Describe Venus. What called? Distance from the Sun? What change of position observable? 357. Greatest distance to which she departs from the Sun? What consequence? How and when seen? 358. What next after these phenomena?

about 46° west of him, where it appears stationary for a few days; then it resumes its course towards the Sun, appearing later and later every morning, until it rises with the Sun, and we cease to behold it. In a few days, the evening star again appears in the west, very near the setting sun, and the same phenomena are again exhibited. Such are the visible appearances of Venus.

359. Venus revolves about the Sun from west to east in 224⅔ days, at the distance of about 68,000,000 of miles, moving in her orbit at the rate of 80,000 miles an hour. She turns around on her axis once in 23 hours, 21 minutes, and 7 seconds. Thus her day is about 25 minutes shorter than ours, while her year is equal to 7½ of our months, or 32 weeks.

360. The mean distance of the Earth from the Sun is estimated at 95,000,000 of miles, and that of Venus being 68,000,000, the diameter of the Sun, as seen from Venus, will be to his diameter as seen from the Earth, as 95 to 68, and the surface of his disc as the square of 95 to the square of 68, that is, as 9025 to 4626, or as 2 to 1, nearly. The intensity of light and heat being inversely as the square of their distances from the Sun (No. 342), Venus receives twice as much light and heat as the Earth.

361. The orbit of Venus is within the orbit of the Earth; for if it were not, she would be seen as often in opposition to the Sun, as in conjunction with him; but she was never seen rising in the east while the Sun was setting in the west. Nor was she ever seen in quadrature, or on the meridian, when the Sun was either rising or setting. Mercury's greatest elongation being about 23° from the Sun, and that of Venus about 46°, the orbit of Venus must be *outside* of the orbit of Mercury.

362. The *true* diameter of Venus is 7700 miles; but her *apparent* diameter and brightness are constantly varying, according to her distance from the Earth. When Venus and the Earth are on the same side of the Sun, her distance from the Earth is only 26,000,000 of miles; when they are on opposite sides of the Sun, her distance is 164,000,000 of miles. Were the whole of her enlightened hemisphere turned towards us, when she is nearest, she would exhibit a light and brilliancy

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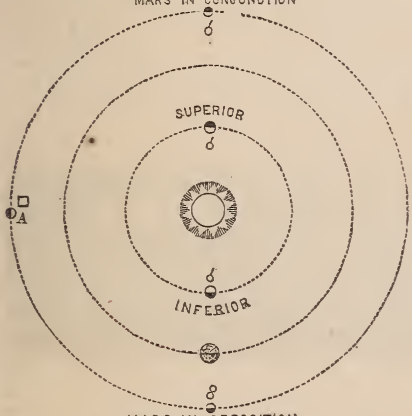
359. What is Venus' sidereal period? Distance from the Sun? Rate of motion? Time of rotation upon her axis? How, then, do her day and year compare with ours? 360. How must the Sun appear from Venus, and why? What of her light and heat? 361. Where is the orbit of Venus situated? What proof of this? 362. Venus' diameter? Her *apparent* diameter? State her least and greatest distances from the Earth

twenty-five times greater than she generally does, and appear like a small brilliant moon ; but, at that time, her dark hemisphere is turned towards the Earth.

When Venus approaches nearest to the Earth, her *apparent*, or observed diameter is 61".2; when most remote, it is only 9".6; now 61".2÷9".6=6⅜, hence when nearest the Earth her apparent diameter is 6⅜ times greater than when most distant, and surface of her disc (6⅜°)² or nearly 41 times greater. In this work, the apparent size of the heavenly bodies is estimated from the apparent surface of their discs, which is always proportional to the squares of their apparent diameters.

363. Mercury and Venus are called *Interior* planets, because their orbits are *within* the Earth's orbit, or between it and the Sun. The other planets are denominated *Exterior*, because their orbits are without or beyond the orbit of the Earth. (Map I.) As the orbits of Mercury and Venus lie *within* the Earth's orbit, it is plain, that once in every synodical revolution, each of these planets will be in conjunction on the same side of the Sun. In the former case, the planet is said to be in its *inferior conjunction*, and in the latter case, in its *superior conjunction ;* as in the following figure.



Let the student imagine himself stationed upon the earth in the cut. Then the sun and three planets above are in *conjunction*. The *inferior* and *superior* are distinguished; while at A, a planet is shown in *quadrature*, and at the bottom of the cut the planet Mars in *opposition* with the sun and interior planet.

The period of Venus' synodical revolution is found in the same manner as that of Mercury; namely, by dividing the whole circumference of her orbit by her mean *relative* motion in a day. Thus, Venus' *absolute* mean daily motion is 1° 36′ 7".8, the Earth's is 59′ 8".3, and their difference is 36′ 59".5. Divide 360° by 36′ 59".5, and it gives 583.920, or nearly 584 days for Venus' synodical revolution, or the period in which she is twice in conjunction with the Earth.

364 When Venus' right ascension is less than that of the Sun, she rises before him ; when greater, she appears after his setting. She continues alternately morning and evening star, for a period of 292 days, each time.

How would she appear if we saw her enlightened side when nearest to us? What computation in the fine print? 363. How are Mercury and Venus distinguished, and why? What said of *conjunctions?* Describe the *inferior* and *superior?* How is the period of Venus' synodical revolution found? 364. When is Venus evening star? Morning?

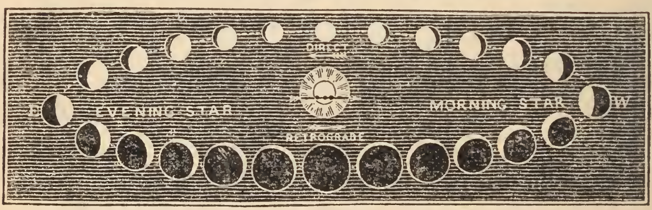
To those who are but little acquainted with astronomy, it will seem strange, at first, that Venus should apparently continue longer on the east or west side of the Sun, than the whole time of her periodical revolution around him. But it will be easily understood, when it is considered, that while Venus moves around the Sun, at the rate of about 1° 36' of angular motion per day, the Earth follows at the rate of 59'; so that Venus actually gains on the Earth, only 37' in a day.

Now it is evident that both planets will appear to keep on the same side of the Sun, until Venus has gained half her orbit, or 180° in advance of the Earth; and this, at a mean rate, will require 292 days, since $292 \times 37' = 10804'$, or 180° nearly.

365. Venus passes from her inferior to her superior conjunction in about 292 days. At her inferior conjunction, she is 26,000,000 of miles from the Earth; at her superior conjunction, 164,000,000 of miles. It might be expected that her brilliancy would be proportionally increased, in the one case, and diminished in the other; and so it would be, were it not that her enlightened hemisphere is turned more and more from us, as she approaches the Earth, and comes more and more into view as she recedes from it. It is to this cause alone that we must attribute the uniformity of her splendor, as it usually appears to the naked eye.

366. Mercury and Venus present to us, successively, the various shapes and appearances of the Moon; waxing and waning through different phases, as shown in the following cut, from the beautiful crescent to the full rounded orb. This fact shows, that they revolve around the Sun, and between the Sun and the Earth.

PHASES OF VENUS AS SHE REVOLVES AROUND THE SUN.



It should be remarked, however, that Venus is never *seen* when she is entirely *full*, except once or twice in a century, when she passes directly over the Sun's disc. At every other conjunction, she is either *behind* the Sun, or so near him as to be hidden by the splendor of his light. The preceding diagram better illustrates the various appearances of Venus, as she moves around the Sun, than any description of them could do.

367. From her inferior to her superior conjunction, Venus, appears on the west side of the Sun, and is then our morning

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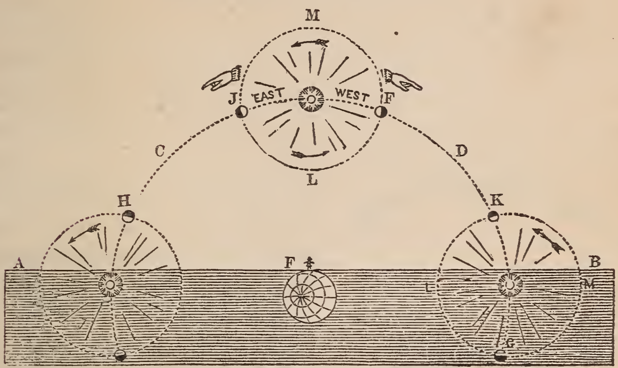
How long each? How is it that Venus is east or west of the Sun 292 days, when her periodic revolution is performed in about 225 days? 365. What is the time from one conjunction of Venus to another? Is her brilliancy in proportion to her nearness? Why not? 366. What phases do Mercury and Venus exhibit, and what do they prove? Are they ever seen entirely *full?* 367. When is Venus morning star? When evening?

star; from her superior to her inferior conjunction she appears on the east side of the Sun, and is then our evening star. These phenomena are illustrated by the following diagram.

VENUS AS MORNING AND EVENING STAR.



Let the student hold the book up *south* of him, and he will at once see why Venus is alternately morning and evening star. Let the plane A B represent the sensible or visible horizon, C D the apparent daily path of the Sun through the heavens, and E the Earth in her apparent position. The Sun is shown at three different points—namely, rising in the east, on the meridian, and setting in the west; while Venus is seen revolving around him from west to east, or in the direction of the arrows. Now it is obvious that when Venus is at F, or *west* of the Sun, she sets before him as at G, and rises before him as at H. She must, therefore, be *morning star*. On the other hand, when she is *east* of the Sun, as at J, she lingers in the west after the Sun has gone down, as at K, and is consequently *evening star*.

In this cut, Venus would be at her greatest elongation *eastward* at J, and *westward* at F, and in both cases would be "*stationary*." At L and M she would be in *conjunction* with the Sun.

Were the earth to suspend her daily rotation, with the Sun on the meridian of the observer, as represented at L, we might readily watch Venus through her whole circuit around the Sun.

368. Like Mercury, Venus sometimes seems to be stationary. Her apparent motion, like his, is sometimes rapid; at one time, *direct*, and at another, *retrograde;* vibrating alternately backwards and forwards, from west to east, and from east to west. These vibrations appear to extend from 45° to 47°, on each side of the Sun.

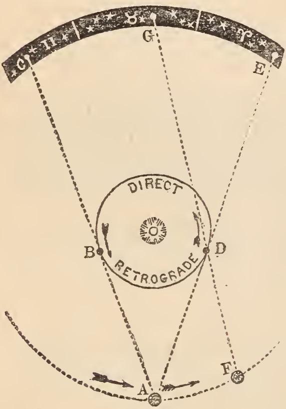
Consequently she never appears in the eastern horizon more than three hours before sunrise, nor continues longer in the western horizon after sunset. Any star or planet therefore, however brilliant it may appear, which is seen earlier or later than this, cannot be Venus.

369. In passing from her western to her eastern elongation,

268. Is she ever *stationary?* What other irregularities in her apparent motion?
369. When is her motion *direct?* When *retrograde?* When most rapid? When

her motion is from west to east, *in the order of the signs;* it is thence called *direct* motion. In passing from her eastern to her western elongation, her motion with respect to the Earth is from east to west, *contrary* to the order of the signs; it is thence denominated *retrograde motion.* Her motion appears quickest about the time of her conjunctions; and she seems stationary at her elongations. She is brightest about thirty-six days before and after her inferior conjunction, when her light is so great as to project a visible shadow in the night, and sometimes she may be seen with the naked eye even at noon-day.

DIRECT AND RETROGRADE MOTIONS.



The cause of the apparent retrogression of the *interior* planets is the fact that they revolve much more rapidly than the earth, from which we view them; causing their direct motion to appear to be retrograde.

Suppose the earth to be at A, and Venus at B, she would appear to be at C, among the stars. If the earth remained at A while Venus was passing from B to D, she would seem to retrograde from C to E; but as the earth passes from A to F while Venus goes from B to D, Venus will appear to be at G; and the amount of her apparent westward motion will only be from C to G.

370. If the orbit of Venus lay exactly in the plane of the Earth's orbit, she would pass centrally across the Sun's disc, like a dark round spot, at every inferior conjunction; but, as one-half of her orbit lies about $3\frac{1}{3}°$ above the ecliptic, and the other half as far below it, she will always pass the Sun a very little above or below it, except when her inferior conjunction happens in, or near one of her nodes; in which case she will make a transit. (See cuts, pages 179 and 180.)

This phenomenon, therefore, is of very rare occurrence; it can happen only twice in a century; because it is only twice in that time that any number of complete revolutions of Venus are just or nearly equal to a certain number of the Earth's revolutions.

The principle which was illustrated in predicting the transits of Mercury, applies equally well to those of Venus; that is, we must find such sets of numbers (representing

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brightest? State the cause of the apparent retrograde motion? 370. Why have we not a transit at every revolution of Venus? How frequent, therefore? How predicted? When do her nodes cut the ecliptic?

complete revolutions of the Earth and Venus) as shall be to each other in the ratio of their periodical times, or as 365.256 is to 224.7. Thus: the motion of Venus, in the Julian years, is 2106591".52; that of the Earth for the same period being 129627".45, the ratio will be $\frac{2106591''.52}{129627''.45}$. As the two terms of this fraction cannot be reduced by a common divisor, we must multiply them by such numbers as will make one a multiple of the other; accordingly, 13 times the denominator will be nearly equal to 8 times the numerator; and 475 times the denominator will equal 291 times the numerator.

By combining these two periods and their multiples by addition and subtraction, we shall obtain the period of all the transits that have ever happened. Thus: $291-8\times7=235$, another period; and $291-6\times8=243$, another period, and so on. Whence we find that

8 periodical revolutions of the Earth are equal to 13 of Venus:
235 periodical revolutions of the Earth are equal to 382 of Venus:
243 periodical revolutions of the Earth are equal to 395 of Venus:
251 periodical revolutions of the Earth are equal to 408 of Venus:
291 periodical revolutions of the Earth are equal to 475 of Venus.

Hence a transit of Venus may happen at the same node, after an interval of 8 years; but if it do not happen then, it cannot take place again at the same node, in less than 235 years. The orbit of Venus crosses the ecliptic near the middle of Gemini and Sagittarius; and these points mark the position of her nodes. At present, her ascending node is in the 14th degree of Gemini, and her descending node in the same degree of Sagittarius.

371. The node months of Venus are December and June. The line of her nodes lies in Gemini (♊) and Sagittarius (♐); and as the Earth always passes those points in the months named, it follows that all transits of Venus must occur in those months for ages to come.

This proposition will be well understood by consulting the cut on page 000; for as the line of Venus' nodes is only one sign ahead of that of Mercury, the Earth will reach that point in the ecliptic in one month after she passes the line of Mercury's nodes; so that if his transits occur in May and November, hers should occur in June and December, as is always the case.

272. The first transit ever known to have been seen by any human being, took place at the ascending node, December 4th, 1639.* If to this date we add 235 years, we shall have the

* This phenomenon was first witnessed by Horrox, a young gentleman about 21 years of age, living in an obscure village 15 miles north of Liverpool. The tables of Kepler, constructed upon the observations of Tycho Brahe, indicated a transit of Venus in 1631, but none was observed. Horrox, without much assistance from books and instruments, set himself to inquire into the error of the tables, and found that such a phenomenon might be expected to happen in 1639. He repeated his calculations during this interval, with all the carefulness and enthusiasm of a scholar ambitious of being the first to predict and observe a celestial phenomenon, which, from the creation of the world, had never been witnessed. Confident of the result, he communicated his expected triumph to a confidential friend residing in Manchester, and desired him to watch for the event, and to take observations. So anxious was Horrox not to fail of witnessing it himself, that he commenced his observations the day before it was expected, and resumed them at the rising of the Sun on the morrow. But the *very hour* when his calculations led him to expect the visible appearance of Venus on the Sun's disc, *was also the appointed hour for the public worship of God on the Sabbath.* The delay of a few minutes might deprive him for ever of an opportunity of observing the transit. If its very commencement were not noticed, clouds might intervene, and conceal it until the Sun should set: and nearly a century and a half would elapse before another opportunity would occur. He had been waiting for the event with the most ardent anticipation for eight years, and the result promised much benefit to the science. *Notwithstanding all this, Horrox twice suspended his observations and twice repaired to the House of God*, the Great Author of the bright works he delighted to contemplate. When his duty was thus per-

371. Which are her node months? 372. When was the first transit observed? What interesting anecdote?

time of the next transit at the same node, which will accordingly happen in 1874. There will be another at the same node in 1882, eight years afterwards. It is not more certain that this phenomenon will recur, than that the event itself will engross the attention of all the astronomers then living upon the Earth. It will be anticipated, and provided for, and observed, in every inhabited quarter of the globe, with an intensity of solicitude which no natural phenomenon, since the creation, has ever excited.

373. The reason why a transit of Venus should excite so great an interest is, because it may be expected to solve an important problem in astronomy, which has never yet been satisfactorily done :—a problem whose solution will make known to us the magnitudes and masses of all the planets, the true dimensions of their orbits, their rates of motion around the Sun, and their respective distances from the Sun, and from each other. It may be expected, in short, to furnish an universal standard of astronomical measure. Another consideration will render the observation of this transit peculiarly favorable ; and that is, astronomers will be supplied with better instruments, and more accurate means of observation, than on any former occasion.

So important, says Sir John Herschel, have these observations appeared to astronomers, that at the last transit of Venus, in 1769, expeditions were fitted out, on the most efficient scale, by the British, French, Russian, and other governments, to the remotest corners of the globe, for the express purpose of making them. The celebrated expedition of Captain Cook to Otaheite, was one of them. The general result of all the observations made on this most memorable occasion, gives 8″.5776 for the Sun's horizontal parallax.

374. The phenomena of the seasons of each of the planets, like those of the Earth, depend upon the inclination of the axis of the planet to the plane of its orbit, and its revolution around the Sun. The inclination of the axis of Venus to the plane of her orbit, though not precisely known, is commonly estimated at 75°, as represented to the eye in the following cut :

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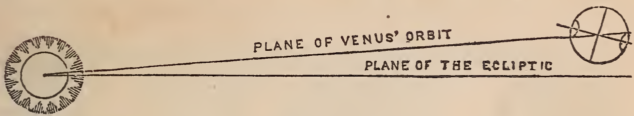
formed, and he had returned to his chamber the second time, his love of science was gratified with full success; and he saw what no mortal eye had observed before!

If anything can add interest to this incident, it is the modesty with which the young astronomer apologizes to the world, for *suspending* his observations at all.

"I observed it," says he, "from sunrise till nine o'clock, again a little before ten, and lastly at noon, and from one to two o'clock; the rest of the day being devoted to higher duties, which might not be neglected for these pastimes."

When the next? When another? How will it be regarded? 373. Why should such an event excite general interest? Remark of Sir John Herschel? What expedition and what results? 374. Upon what do the *seasons* of the planets depend? What is the inclination of Venus' axis to the plane of her orbit? How is her orbit situated with reference to the ecliptic?

INCLINATION OF VENUS' AXIS.



The *orbit* of Venus departs from the *ecliptic* 3½°, while her *axis* is inclined to the plane of her orbit 75°, as shown in the above figure. This distinction should be kept definitely in view by the student.

375. The declination of the Sun on each side of Venus' equator, must be equal to the inclination of her axis ; and if this extends to 75°, her tropics are only 15° from her poles, and her polar circles only 15° from her equator. It follows, also, that the Sun must change his declination more in one day at Venus, than in five days on the Earth ; and, consequently, that he never shines vertically on the same places for two days in succession. This may, perhaps, be providentially ordered, to prevent the too great effect of the Sun's heat, which, on the supposition that it is in inverse proportion to the square of the distance, is twice as great on this planet as it is on the Earth.

376. At each pole of Venus, the Sun continues half of her year without setting in summer, and as long without rising in winter ; consequently, her polar inhabitants, like those of the Earth, have only one day and one night in the year ; with this difference, that the polar days and nights of Venus are not quite two-thirds as long as ours.

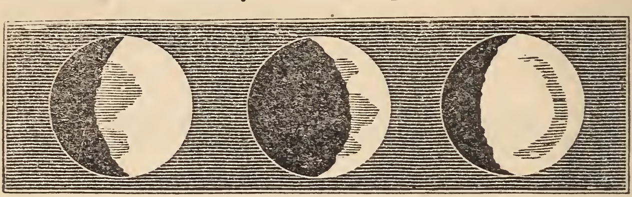
Between her polar circles, which are but 15° from her equator, there are two winters, two summers, two springs, and two autumns, every year. But because the Sun stays for some time near the tropics, and passes so quickly over the equator, the winters in that zone will be almost twice as long as the summers.

The north pole of Venus' axis inclines towards the 20th degree of Aquarius ; the Earth's towards the beginning of Cancer ; consequently, the northern parts of Venus have summer in the signs where those of the Earth have winter, and *vice versâ*.

377. When viewed through a good telescope, Venus exhibits not only all the moon-like phases of Mercury, but also a variety of inequalities on her surface ; dark spots, and brilliant shades, hills and valleys, and elevated mountains. But on account of

375. What is the amount of the Sun's declination upon Venus? What results? What supposed design in this arrangement? 376. What said of the polar regions of Venus? What of her seasons? How is her north pole situated with respect to the heavens? What consequence? 377. How does Venus appear through a telescope?

the great density of her atmosphere, these inequalities are perceived with more difficulty than those upon the other planets.



378. The mountains of Venus, like those of Mercury and the Moon, are highest in the southern hemisphere. According to M. Schroeter, a celebrated German astronomer, who spent more than ten years in observations upon this planet, some of her mountains rise to the enormous height of from ten to twenty-two miles. The observations of Dr. Herschel do not indicate so great an altitude ; and he thinks, that in general they are considerably overrated. He estimates the diameter of Venus at 8649 miles ; making her bulk more than one-sixth larger than that of the Earth. Several eminent astronomers affirm, that they have repeatedly seen Venus attended by a satellite, and they have given circumstantial details of its size and appearance, its periodical revolution and its distance from her. It is said to resemble our Moon in its phases, its distance, and its magnitude. Other astronomers deny the existence of such a body, because it was not seen with Venus on the Sun's disc, at the transits of 1761 and 1769.

THE EARTH.

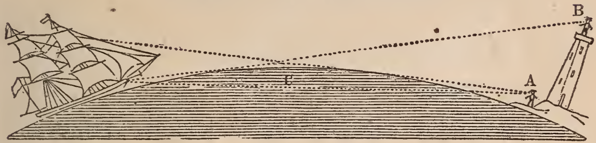
379. The Earth is the place from which all our observations of the heavenly bodies must necessarily be made. The apparent motions of these bodies being very considerably affected by her figure, motions, and dimensions, these hold an important place in astronomical science. It will, therefore, be proper to consider, first, some of the methods by which they have been determined.

If, standing on the sea-shore, in a clear day, we view a ship leaving the coast, *in any direction*, the hull or body of the vessel

Why less distinct than the other planets? 378. Where are her highest mountains situated? Their height? Remark of Dr. Herschel? His estimate of Venus' diameter? What said about a *satellite* around Venus? 379. Relation of the earth to the other planets in the study of astronomy? What necessary, therefore? What proof of the convexity of her surface?

first disappears; afterwards the rigging, and lastly the top of the mast vanishes from our sight.

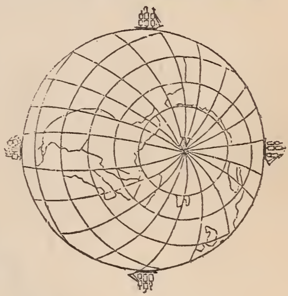
CONVEXITY OF THE EARTH'S SURFACE.



Here the observer upon the shore at A sees only the topmasts of the ship, while the man standing upon the pillar at B sees the masts and sails, and part of the hull. Now, if the water between A and the ship were exactly flat instead of convex, the vision of A would extend along the line C, and he could see the whole ship as well as B. The advantage of B over A, in consequence of his elevation, shows that the surface of the water is convex between A and the ship.

380. Again: navigators have sailed quite around the Earth, and thus proved its convexity.

CONVEXITY OF THE EARTH'S SURFACE.



Ferdinand Magellan, a Portuguese, was the first who carried this enterprise into execution. He embarked from Seville, in Spain, and directed his course towards the west. After a long voyage, he descried the continent of America. Not finding an opening to enable him to continue his course in a westerly direction, he sailed along the coast towards the south, till, coming to its southern extremity, he sailed around it, and found himself in the great Southern Ocean. He then resumed his course towards the west. After some time he arrived at the Molucca Islands, in the *Eastern Hemisphere;* and sailing continually towards the west, he made Europe from the east, arriving at the place from which he set out.*

The next who circumnavigated the Earth was Sir Francis Drake, who sailed from Plymouth, December 13, 1577, with five small vessels, and arrived at the same place, September 26, 1580. Since that time, the circumnavigation of the Earth has been performed by Cavendish, Cordes, Noort, Sharten, Heremites, Dampier, Woodes, Rogers, Schovten, Roggewin, Lord Anson, Byron, Carteret, Wallis, Bougainville, Cook, King, Clerk, Vancouver, and many others.

381. These navigators, by sailing in a westerly direction, allowance being made for promontories, &c., arrived at the country they sailed from. Hence the Earth must be either cylindrical or globular. It cannot be cylindrical, because, if so, the meridian distances would all be equal to each other, which is

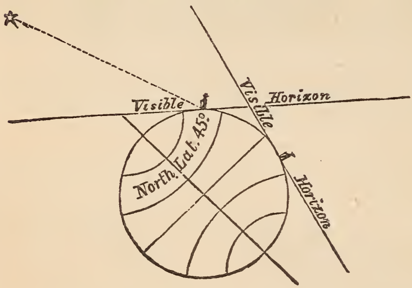
* Magellan sailed from Seville, in Spain, August 10, 1519, in the ship called the Victory, accompanied by four other vessels. In April, 1521, he was killed in a skirmish with the natives, at the island of *Sebu*, or *Zebu*, sometimes called Matan, one of the Philippines. One of his vessels, however, arrived at St. Lucar, near Seville, September 7, 1522.

380. What *second* proof stated? Who first sailed around the world? Who next?
381. In what direction did they sail? How did these voyages prove the earth to be

contrary to observation. The figure of the Earth is, therefore, spherical.

382. The convexity of the Earth, north and south, is proved by the variation in the altitude of the pole, and of the circumpolar stars ; this is found uniformly to increase as we approach them, and to diminish as we recede from them.

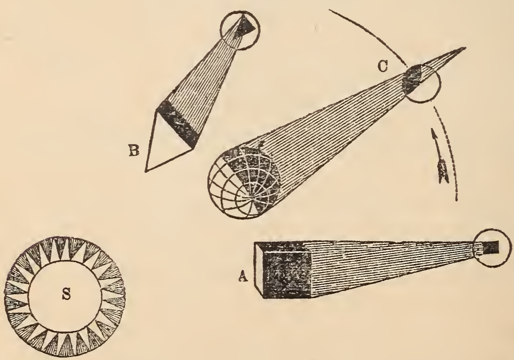
LATITUDE FOUND BY THE NORTH STAR.



Suppose an observer standing upon the Earth, and viewing the pole star from the 45° of North latitude; it would, of course, appear elevated 45° above his visible horizon. But let him recede southward, and as he passed over a degree of latitude, the pole star would settle one degree towards the horizon, or more properly, his northern horizon would be elevated one degree towards the pole star, till at length, as he crossed the equator, the North star would sink below the horizon, and become invisible. Whence we derive the general rule, that *the altitude of one pole, or the depression of the other, at any place on the Earth's surface, is equal to the latitude of that place.*

383. The form of the Earth's shadow, as seen upon the Moon in an eclipse, indicates the globular figure of the Earth, and the consequent convexity of its surface.

FORM OF THE EARTH'S SHADOW.



spherical? 382. What further proof have we that the earth is spherical? What rule based upon this phenomenon? 383. What other evidence that the earth is a globe What remarks respecting the curvature of the earth's surface? What rules laid down based upon this curvature?

Were the Earth a *cube* as shown at A, or in the form of a *prism*, as represented at B, her shadow would be more or less cubical or prismatic, as seen in the cut; but instead of this, it is *convex on all sides*, as represented at C, plainly indicating the convexity of the Earth by which it is caused.

The curvature of the Earth for one mile is 8 inches; and this curvature increases with the square of the distance. From this general law it will be easy to calculate the distance at which any object whose height is given, may be seen, or to determine the height of an object when the distance is known.

1st. To find the height of the object when the distance is given.

RULE. *Find the square of the distance in miles, and take two-thirds of that number for the height in feet.*

Ex. 1.—How high must the eye of an observer be raised, to see the surface of the ocean at the distance of three miles? *Ans.* The square of 3 ft. is 9 ft., and ⅔ of 9 ft. is 6 ft. Ex. 2.—Suppose a person can just see the top of a spire over an extended plain of ten miles, how high is the steeple? *Ans.* The square of 10 is 100, and ⅔ of 100 is 66⅔ feet.

2. To find the distance when the height is given.

RULE. *Increase the height in feet one-half, and extract the square root, for the distance in miles.*

Ex. 1.—How far can a person see the surface of a plain, whose eye is elevated six feet above it? *Ans.* 6, increased by half, is 9, and the square root of 9 is 3: the distance is then 3 miles. Ex. 2.—To what distance can a person see a lighthouse whose height is 96 feet from the level of the ocean? *Ans.* 96 increased by its half, is 144, and the square root of 144, is 12; the distance is therefore 12 miles.

3. To find the curvature of the Earth when it exceeds a mile.

RULE. *Multiply the square of the distance by* .000126.

384. Although it appears from the preceding facts, that the Earth is spherical, yet it is not a perfect sphere. If it were, the length of the degrees of latitude, from the equator to the poles, would be uniformly the same; but it has been found, by the most careful measurement, that as we go from the equator towards the poles, the length *increases with the latitude.*

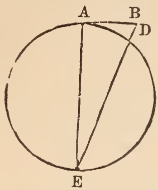
These measurements have been made by the most eminent mathematicians of different countries, and in various places, from the equator to the arctic circle. They have found that a degree of latitude at the arctic circle was *nine-sixteenths* of a mile longer than a degree at the equator, and that the ratio of increase for the intermediate degrees was nearly as the squares of the sines of the latitude. Thus the theory of Sir Isaac Newton was confirmed, that the body of the Earth was more rounded and convex between the tropics, but considerably flattened towards the poles.

Places of Observation.	*Latitude.*	*Length of a degree in English miles.*	*Observers.*
Peru	Equator.	68.732	Bouguer,
Pennsylvania	39° 12′ N.	68.896	Mason and Dixon,
Italy	43 01	68.998	Boscovich and Lemaire,
France	46	69.054	Delambre and Mechain,
England	51 29 54″	69.146	Mudge,
Sweden	66 20 10	69.292	Swamberg.

385. These measurements prove the Earth to be an *oblate spheroid*, whose longest or equatorial diameter is 7924 miles, and polar diameter, 7898 miles. The mean diameter is, therefore, about 7912, and their difference 26 miles. The French Acade-

384. But is the earth a *sphere?* What proof to the contrary? 385. What, then, is the earth's real figure? What difference in her polar and equatorial diameters? What demonstration that the earth is not an exact sphere?

my have determined that the mean diameter of the Earth, from the 45th degree of north latitude, to the opposite degree of south latitude, is *accurately* 7912 miles.



If the Earth were an exact sphere, its diameter might be determined by its curvature, from a single measurement. Thus, in the adjoining figure, we have A B equal to 1 mile, and B D equal to 8 inches, to find A E, or B E, which does not sensibly differ from A E, since B D is only 8 inches. Now it is a proposition of Euclid (B. 3, prop. 36), that, when from a point without a circle, two lines be drawn, one cutting and the other touching it, the touching line (B A) is a mean proportional between the cutting line (B E) and that part of it (B D) without the circle.

B D : B A : : B E or A E very nearly.

That is, 1 mile being equal to 63,360 inches,

8 : 63,360 : : 63,360 : 50,181,120 inches, or 7920 miles.

This is very nearly what the most elaborate calculations make the Earth's equatorial diameter.

386. The Earth, considered as a planet, occupies a favored rank in the Solar System. It pleased the All-wise Creator to assign its position among the heavenly bodies, where nearly all the sister planets are visible to the naked eye. It is situated next to Venus, and is the third planet from the Sun.

To the scholar who for the first time takes up a book on astronomy, it will no doubt seem strange to find the Earth classed with the heavenly bodies. For what can appear more unlike, than the Earth, with her vast and seemingly immeasurable extent, and the stars, which appear but as points? The Earth is dark and opaque, the celestial bodies are brilliant. We perceive in it no motion; while in them we observe a continual change of place, as we view them at different hours of the day or night, or at different seasons of the year.

387. It moves round the Sun from west to east, in 365 days, 5 hours, 48 minutes, and 48 seconds; and turns the same way, on its axis, in 23 hours, 56 minutes, and 4 seconds. The former is called its *annual* motion, and causes the vicissitudes of the seasons. The latter is called its *diurnal* motion, and produces the succession of day and night.

The Earth's mean distance from the Sun is about 95,000,000 of miles. It consequently moves in its orbit at the mean rate of 68,000 miles an hour. Its equatorial diameter being 7924 miles, it turns on its axis at the rate of 1040 miles an hour.

Thus, the Earth on which we stand, and which has served for ages as the unshaken foundation of the firmest structures, is every moment turning swiftly on its center, and, at the same time, moving onwards with great rapidity through the empty space.

This compound motion is to be understood of the *whole Earth*, with all that it holds within its substance, or sustains upon its surface—of the solid mass beneath, of the ocean which flows around it, of the air that rests upon it, and of the clouds which float above it in the air.

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386. What said of the position of the earth in the system? What remark as to classifying the earth as a planet? 387. State the time of the earth's revolution around the Sun? On her own axis? What are they called, respectively? What is the earth's mean distance from the sun? Its mean rate of motion in its orbit? Hourly motion of bodies at the equator? What twofold motion there? Includes what?

388. That the Earth, in common with all the planets, revolves around the Sun as a center, is a fact which rests upon the clearest demonstrations of philosophy. That it revolves, like them, upon its own axis, is a truth which every rising and setting sun illustrates, and which very many phenomena concur to establish. Either the Earth moves around its axis every day, or *the whole universe* moves around it in the same time. There is no third opinion that can be formed on this point. Either the Earth must revolve on its axis every twenty-four hours, to produce the alternate succession of day and night, or the Sun, Moon, planets, comets, fixed stars, and the whole frame of the universe itself, must move around the Earth, in the same time.

389. To suppose the latter case to be the fact, would be to cast a reflection on the wisdom of the Supreme Architect, whose laws are universal harmony. As well might the beetle, that in a moment turns on its ball, imagine the heavens and the earth had made a revolution in the same instant. It is evident, that in proportion to the distance of the celestial bodies from the Earth, must, on this supposition, be the rapidity of their movements. The Sun, then, would move at the rate of more than 400,000 miles in a minute ; the nearest stars, at the inconceivable velocity of 1,400,000,000 of miles in a *second;* and the most distant luminaries, with a degree of swiftness which no numbers could express, and all this, to save the little globe we tread upon, from turning safely on its axis, once in twenty-four hours.

390. The idea of the heavens revolving about the Earth, is encumbered with innumerable other difficulties. We will mention only one more. It is estimated on good authority, that there are visible, by means of glasses, no less than 100,000,000 of stars, scattered at all possible distances in the heavens above, beneath, and around us. Now, is it in the least degree probable, that the velocities of all these bodies should be so regulated, that, though describing circles so very different in dimensions, they should complete their revolutions in exactly the same time? In short, there is no more reason to suppose that the heavens revolve around the Earth, than there is to suppose that they revolve around each of the other planets, separately, and at the same time ; since the same apparent revolution is common to them all, for they all appear to revolve upon their axis, in different periods.

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388. What two motions has the earth? What proof of her diurnal revolution? 389. Why not suppose the heavens revolve around us? 390. What further proof?

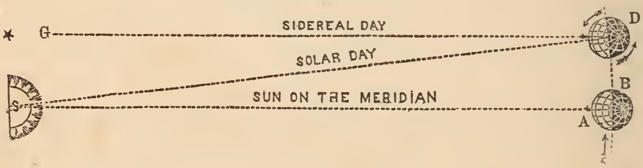
391. The rotation of the Earth determines the length of the day, and may be regarded as one of the most important elements in astronomical science. It serves as an universal measure of time, and forms the standard of comparison for the revolutions of the celestial bodies, for all ages, past and to come. Theory and observation concur in proving, that among the innumerable vicissitudes that prevail throughout creation, the period of the Earth's diurnal rotation is immutable.

SOLAR AND SIDEREAL TIME.

392. The Earth performs one complete revolution on its axis in 23 hours, 56 minutes, and 4.09 seconds, of solar time. This is called a *sidereal day*, because, in that time, the stars appear to complete one revolution around the Earth.

But, as the Earth advances almost a degree eastward in its orbit, in the time that it turns eastward around its axis, it is plain that just one rotation never brings the same meridian around from the Sun to the Sun again ; so that the Earth requires as much more than one complete revolution on its axis to complete a *solar day*, as it has gone forward in that time.

SOLAR AND SIDEREAL TIME.



To the man at A the Sun (S) is exactly on the meridian, or it is twelve o'clock, noon. The Earth passes on from B to D, and at the same time revolves on her axis. When she reaches D, the man who has stood on the same meridian has made a complete revolution, as determined by the star G (which was also on his meridian at twelve o'clock the day before) ; but the Sun is now *east* of the meridian, and he must wait *four minutes* for the Earth to roll a little further eastward, and bring the Sun again over his north and south line. If the Earth was not revolving around the Sun, her solar and sidereal days would be the same ; but as it is, she has to perform a little more than one complete revolution each solar day, to bring the Sun on the meridian.

393. It is obvious, therefore, that in every natural or solar day, the Earth performs one complete revolution on its axis, and the 365th part of another revolution. Consequently, in 365 days, the Earth turns 366 times around its axis. And as every

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391. What relation has the earth's diurnal revolution to *time?* What said of its regularity? 392. What is the time required for a complete revolution? Explain the difference between *solar* and *sidereal* time? 393. Is a solar day more than a complete revolution of the earth on her axis? To what does this excess amount in a year?

revolution of the earth on its axis completes a sidereal day, there must be 366 sidereal days in a year. And, generally, since the rotation of any planet about its axis is the length of a sidereal day at that planet, the number of sidereal days will always exceed the number of solar days by one, let that number be what it may, one revolution being always lost in the course of an annual revolution. This difference between the sidereal and solar days may be illustrated by referring to a watch or clock. When both hands set out together, at 12 o'clock for instance, the minute hand must travel more than a whole circle before it will overtake the hour hand, that is, before they will come into conjunction again.

394. In the same manner, if a man travel around the Earth *eastwardly*, no matter in what time, he will reckon *one day more*, on his arrival at the place whence he set out, than they do who remain at rest; while the man who travels around the Earth *westwardly* will have *one day less*. From which it is manifest, that if two persons start from the same place at the same time, but go in contrary directions, the one traveling eastward and the other westward, and each goes completely around the globe, although they should both arrive again at the very same hour at the same place from which they set out, yet they will disagree two whole days in their reckoning. Should the day of their return, to the man who traveled westwardly, be Monday, to the man who travelled eastwardly, it would be Wednesday; while to those who remained at the place itself, it would be Tuesday.

395. Nor is it necessary, in order to produce the gain or loss of a day, that the journey be performed either on the equator, or on any parallel of latitude: it is sufficient for the purpose, that all the meridians of the Earth be passed through, eastward or westward. The time, also, occupied in the journey, is equally unimportant; the gain or loss of a day being the same, whether the Earth be traveled around in 24 years, or in as many hours.

396. It is also evident, that if the Earth turned around its axis but once in a year, and if the revolution was performed the same way as its revolution around the Sun, there would be perpetual day on one side of it, and perpetual night on the other.

Hence what general rule? What illustration referred to? 394. What effect has traveling east or west, upon time? Hence what result? 395. Is it important that the supposed journeys be performed in a short period? 396. How would it be if the Earth revolved on her axis but once a year?

From these facts the pupil will readily comprehend the principles involved in a curious problem which appeared a few years ago. It was gravely reported by an American ship, that, in sailing over the ocean, it chanced to find *six Sundays in February*. The *fact* was insisted on, and a solution demanded. There is nothing absurd in this. The man who travels around the earth *eastwardly*, will see the Sun go down a little earlier every succeeding day, than if he had remained at rest; or earlier than they do who live at the place from which he set out. The faster he travels towards the rising sun, the sooner will it appear above the horizon in the morning, and so much sooner will it set in the evening. What he thus gains in *time*, will bear the same proportion to a solar day, as the distance traveled does to the circumference of the Earth. As the globe is 360 degrees in circumference, the Sun will appear to move over one twenty-fourth part of its surface, or 14° every hour, which is 4 minutes to *one degree*. Consequently, the Sun will rise, come to the meridian, and set, 4 minutes sooner, at a place 1° east of us, than it will with us; at the distance of 2° the Sun will rise and set 8 minutes sooner; at the distance of 3°, 12 minutes sooner, and so on.

Now the man who travels one degree to the east, the first day will have the Sun on his meridian 4 minutes sooner than we do who are at rest; and the second day 8 minutes sooner, and on the third day 12 minutes sooner, and so on; each successive day being completed 4 minutes earlier than the preceding, until he arrives again at the place from which he started: when this continual gain of 4 minutes a day will have amounted to a whole day *in advance* of our time: he having seen the Sun rise and set *once more* than we have. Consequently, the day on which he arrives at home, whatever day of the week it may be, is one day in advance of ours, and he must needs live that day over again, by calling the next day by the same name, in order to make the accounts harmonize.

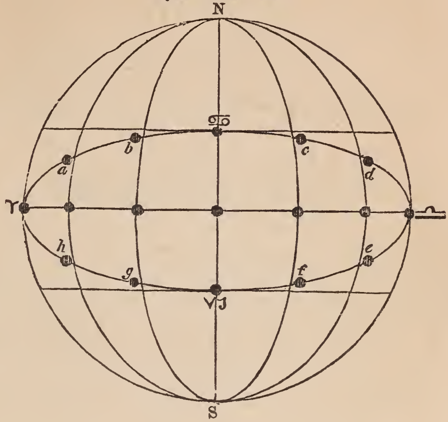
If this should be the last day of February in a bissextile year, it would also be the same day of the week that the *first* was, and be six times repeated, and if it should happen on Sunday, he would, under these circumstances, have six Sundays in February.

Again: whereas the man who travels at the rate of one degree to the east, will have all his days 4 minutes *shorter* than ours, so, on the contrary, the man who travels at the same rate towards the west, will have all his days 4 minutes *longer* than ours. When he has finished the circuit of the Earth, and arrived at the place from which he first set out, he will have seen the Sun rise and set *once less* than we have. Consequently, the day he gets home will be *one day after* the time at that place; for which reason, if he arrives at home on Saturday, according to his own account, he will have to call the next day *Monday;* Sunday having gone by before he reached home. Thus, on whatever day of the week January should end, in common years, he would find the same day repeated only three times in February. If January ended on Sunday, he would, under these circumstances, find only *three Sundays in February*.

397. The Earth's motion about its axis being perfectly equable and uniform in every part of its annual revolution, the sidereal days are always of the same length, but the solar or natural days vary very considerably at different times of the year. This variation is owing to two distinct causes, the inclination of the Earth's axis to its orbit, and the inequality of its motion around the Sun. From these two causes it is, that the time shown by a well-regulated clock and that of a true sun-dial are scarcely ever the same. The difference between them, which sometimes amounts to 16¼ minutes, is called the *Equation of Time*, or the equation of solar days.

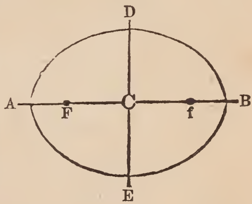
What curious facts accounted for? What supposition of a man traveling eastward one degree a day? What effect upon the time of the Sun's passing the meridian? Upon the *length* of his day? What change of *name* may it require? 397. Are the solar and sidereal days alike uniform as to length? Why do solar days vary in length? Why do not a *dial* and *clock* agree? What is the *Equation of Time?*

EQUATION OF TIME



The difference between *mean* and *apparent* time, or, in other words, between *Equinoctial* and *Ecliptic* time, may be further shown by this figure, which represents the circles of the sphere. Let it be first premised, that *equinoctial* time is *clock* time; and that *ecliptic* time is *solar* or *apparent* time. It appears that from Aries to Cancer, the Sun in the ecliptic comes to the meridian *before* the equinoctial Sun; from Cancer to Libra, *after* it; from Libra to Capricorn *before* it; and from Capricorn to Aries *after* it. If we notice what months the Sun is in these several quarters, we shall find that from the 25th of December to the 16th of April, and from the 16th of June to the 1st of September, the *clock is faster* than the sun-dial; and that, from the 16th of April to the 16th of June, and from the 1st of September to the 25th of Dec., the *sun-dial* is faster than the clock.

398. It is an universal fact, that, while none of the planets are perfect spheres, none of their orbits are perfect circles. The planets all revolve about the Sun, in ellipses of different degrees of eccentricity; having the Sun, not in the center of the ellipse, but in one of its foci.



The figure A D B E is an *ellipse*. The line A B is called the transverse axis, and the line drawn through the middle of this line, and perpendicular to it, is the conjugate axis. The point C, the middle of the transverse axis, is the *center* of the ellipse. The points F and f, equally distant from C, are called the *foci*. C F, the distance from the center to one of the foci, is called the eccentricity. The orbits of the planets being ellipses, having the Sun in one of the foci, if A D B E be the orbit of a planet, with the Sun in the focus F, when the planet is at the point A, it will be in its *perihelion*, or nearest the Sun; and when at the point B in its *aphelion*, or at its greatest distance from the Sun. The difference in these distances is evidently equal to F f, that is, equal to twice the eccentricity of its orbit. In every revolution, a planet passes through its perihelion and aphelion. The eccentricity of the Earth's orbit is about one and a half millions of miles; hence she is 3,000,000 of miles nearer the Sun in her perihelion, than in her aphelion.

Now as the Sun remains fixed in the lower focus of the Earth's orbit, it is easy to perceive that a line, passing centrally through the Sun at right angles with the longer axis of the orbit, will divide it into two unequal segments. *Precisely thus it is divided by the equinoctial.*

399. That portion of the Earth's orbit which lies *above* the

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398. What is the true form of the planets' orbits? Why is equinoctial time irregular?
399. How is the Earth's orbit divided by the equinoctial?

Sun, or *north* of the equinoctial, contains about 184 degrees; while that portion of it which lies *below* the Sun, or *south* of the equinoctial, contains only 176 degrees. This fact shows why the Sun continues about eight days longer on the north side of the equator in summer, than it does on the south side in winter. The exact calculation, for the year 1830, is as follows:

		d.	h.	m.	d.	h.	m.
From the vernal equinox to the summer solstice,	=	92	21	19	183	11	19
From the summer solstice to the autumnal equinox,	=	93	14	1			
From the autumnal equinox to the winter solstice,	=	89	17	17	178	18	30
From the winter solstice to the vernal equinox,	=	89	1	13			
Difference in favor of the north side,					= 7	16	49

The points of the Earth's orbit which correspond to its greatest and least distances from the Sun, are called, the former the *Apogee*, and the latter the *Perigee;* two Greek words, the former of which signifies *from the Earth*, and the latter *about the Earth.* These points are also designated by the common name of *Apsides.*

400. The Earth being in its perihelion about the 1st of January, and in its aphelion the 1st of July, we are 3,000,000 of miles nearer the Sun in winter than in midsummer. The reason why we have not, as might be expected, the hottest weather when the Earth is nearest the Sun, is, because the Sun, at that time, having retreated to the southern tropic, shines so obliquely on the northern hemisphere, that its rays have scarcely half the effect of the summer Sun; and continuing but a short time above the horizon, less heat is accumulated by day than is dissipated by night.

401. As the Earth performs its annual revolution around the Sun, the position of its axis remains invariably the same; always pointing to the North Pole of the heavens, and always maintaining the same inclination to its orbit. This seems to be providentially ordered for the benefit of mankind. If the axis of the Earth always pointed to the center of its orbit, all external objects would appear to whirl about our heads in an inexplicable maze. Nothing would appear permanent. The mariner could no longer direct his course by the stars, and every index in nature would mislead us.

What phenomenon does this explain? 400. When is the Earth in its perihelion? Its aphelion? What difference in its distance from the Sun? Why, then, have we not the warmest weather in January? 401. What said of the permanency of the Earth's axis? How would it be if either pole was toward the Sun?

CHAPTER IV.

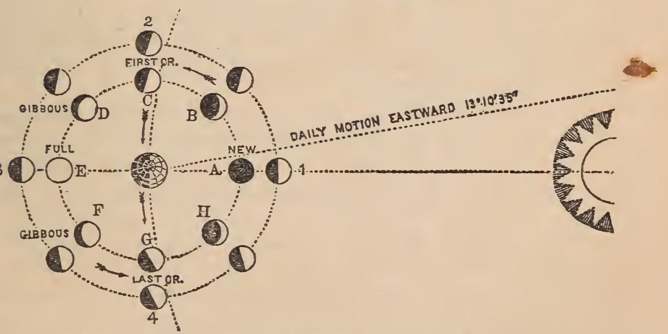
THE MOON—HER DISTANCE, MOTIONS, PHASES, &c.

402. THERE is no object within the scope of astronomical observation which affords greater variety of interesting investigation than the various phases and motions of the Moon. From them the astronomer ascertains the form of the Earth, the vicissitudes of the tides, the causes of eclipses and occultations, the distance of the Sun, and, consequently, the magnitude of the solar system. These phenomena, which are perfectly obvious to the unassisted eye, served as a standard of measurement to all nations, until the advancement of science taught them the advantages of solar time. It is to these phenomena that the navigator is indebted for that precision of knowledge which guides him with well-grounded confidence through the pathless ocean.

The Hebrews, the Greeks, the Romans, and, in general, all the ancients, used to assemble at the time of new or full Moon, to discharge the duties of piety and gratitude for her unwearied attendance on the Earth, and all her manifold uses.

The philosophy of the *changes* of the Moon is illustrated by the following cut :

PHILOSOPHY OF THE MOON'S CHANGES.



This cut represents the moon revolving eastward around the Earth. In the outside circle, she is represented as she would appear, if viewed from a direction at right angles with the plane of her orbit. The side toward the Sun is enlightened in every case, and she appears like a half moon at every point.

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402. What said of the Moon's motions and phases? What learned from them? How used anciently? How at the present time? How did the ancients observe the new and full moons?

The interior suit represents her as she appears when viewed from the earth. At A it is New Moon; and if seen at all so near the Sun, she would appear like a dark globe. At B she would appear like a crescent, concave toward the east. At C, more of her enlightened side is visible; at D still more; and at E the enlightened hemisphere is fully in view. We then call her a *Full Moon*. From E around to A again, the dark portion becomes more and more visible, as the luminous part goes out of view, till she comes to her change at A. When at D and F the moon is said to be *gibbous*.

403. When the Moon, after having been in conjunction with the Sun, emerges from his rays, she first appears in the evening, a little after sunset, like a fine luminous crescent, with its convex side towards the Sun. If we observe her the next evening, we find her about 13° farther east of the Sun than on the preceding evening, and her crescent of light sensibly augmented. Repeating these observations, we perceive that she departs farther and farther from the Sun, as her enlightened surface comes more and more into view, until she arrives at her *first quarter*, and comes to the meridian at sunset. She has then finished half her course from the new to the full, and half her enlightened hemisphere is turned towards the Earth.

404. After her first quarter, she appears more and more *gibbous*, as she recedes farther and farther from the Sun, until she has completed just half her revolution around the Earth, and is seen rising in the east when the Sun is setting in the west. She then presents her enlightened orb *full* to our view, and is said to be in *opposition;* because she is then on the opposite side of the Earth with respect to the Sun.

In the first half of her orbit she appears to pass over our heads through the upper hemisphere; she now descends below the eastern horizon to pass through that part of her orbit which lies in the lower hemisphere.

405. After her full she wanes through the same changes of pearance as before, but in an inverted order; and we see her in the morning like a fine thread of light, a little west of the rising Sun. For the next two or three days she is lost to our view, rising and setting in *conjunction* with the Sun; after which, she passes over, by reason of her daily motion, to the *east* side of the Sun, and we behold her again, a new Moon, as before. In changing sides with the Sun, she changes also the direction of her crescent. Before her conjunction it was turned to the east; it is now turned towards the west. These different appearances of the Moon are called her *phases*. They prove that she shines

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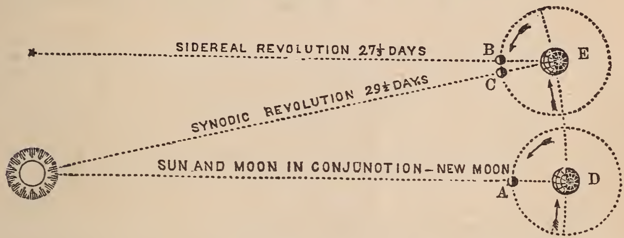
403. Explain the cause of the changes of the Moon? 404. How after her first quarter? 405. How after her full? What change in her crescent? What do the Moon's phases prove?

not by any light of her own ; if she did, being globular, we should always see her a round full orb like the Sun.

406. The Moon is a satellite to the Earth, about which she revolves in an elliptical orbit, in 29 days, 12 hours, 44 minutes, and 3 seconds ; the time which elapses between one new moon and another. This is called her *synodic* revolution. Her revolution from any fixed star to the same star again, is called her *periodic* or *sidereal* revolution. It is accomplished in 27 days, 7 hours, 43 minutes, and 11½ seconds ; but in this time, the Earth has advanced nearly as many *degrees* in her orbit ; consequently, the Moon, at the end of one complete revolution, must go as many degrees farther, before she will come again into the same position with respect to the Sun and the Earth.

SIDEREAL AND SYNODIC REVOLUTIONS OF THE MOON.



On the right, the earth is shown in her orbit, revolving around the sun, and the moon in her orbit, revolving around the earth. At A, the sun and moon are in *conjunction*, or it is *New Moon.* As the earth passes from D to E, the moon passes around from A to B, or the exact point in her orbit where she was 27⅓ days before. But she is still west of the sun, and must pass on from B to C, or 1 day and 20 hours longer, before she can again come in conjunction with him. This 1 day and 20 hours constitutes the difference between a sidereal and a synodic revolution.

The student will perceive that the difference between a sidereal and synodic revolution of the moon, like that between solar and sidereal time, is due to the same cause, namely, the revolution of the earth around the sun.

407. Lying along the Moon's path, there are nine conspicuous stars that are used by nautical men for determining their longitude at sea, thence called *nautical stars*. These stars are, *Arietes*, *Aldebaran*, *Pollux*, *Regulus*, *Spica Virginis*, *Antares*, *Altaire*, *Fomalhaut*, and *Markab*.

The true places of these stars, for every day in the year, are given in the Nautical Almanac, a valuable work published annually by the English "Board of Admiralty," to guide mariners in navigating the seas. They are usually published two or three years in advance, for the benefit of long voyages

Let A in the cut represent Greenwich Observatory, near London. B is the Moon, and C her apparent place among the distant stars, about 40° west of the star D. The ship E, having Greenwich time, as well as her own local time, sails from London westward ;

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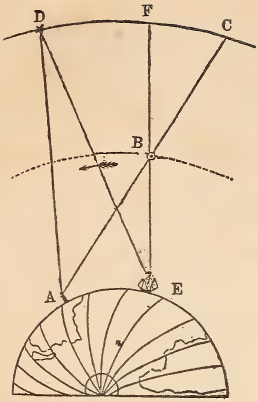
406. Form of the lunar orbit ? Time of *synodic* revolution ? Of *sidereal* revolution ? What difference ? 407. What are the *nautical stars ?* Can you explain how longitude is ascertained by them ?



but on observing the Moon when, by Greenwich time, she ought to be at C, she is found to be at F, or only about 20° west of the star D. It is, therefore, obvious that the *ship* is *west* of Greenwich, as the Moon appears *east* of her Greenwich place. From this difference between her place as laid down in the tables, and her observed place, as referred to certain prominent stars, the mariner determines how far he is east or west of the meridian of Greenwich. The Moon's geocentric place (or place as viewed from the center of the Earth) may be given instead of her Greenwich place, and the same conclusions arrived at. In either case, this is called the *lunar method* of determining the longitude. It is also ascertained by simple comparison of local and standard time, that a man, says Sir John Herschel, by merely measuring the Moon's apparent distance from a star, with a little portable instrument held in his hand, and applied to his eye, even with so unstable a footing as the deck of a ship, shall say positively within five miles where he is, on a boundless ocean, cannot but appear to persons ignorant of physical astronomy an approach to the miraculous. And yet, says he, the alternatives of life and death, wealth and ruin, are daily and hourly staked, with perfect confidence, on these marvellous computations.

408. The Moon is the nearest of all the heavenly bodies, being about thirty times the diameter of the Earth, or 240,000 miles, distant from us. Her mean daily motion in her orbit is nearly fourteen times as great as the Earth's ; since she not only accompanies the Earth around the Sun every year, but, in the mean time, performs nearly thirteen revolutions about the Earth.

Although the apparent motion of the Moon in her orbit is greater than that of any other heavenly body, since she passes over, at a mean rate, no less than 13° 10′ 35″ in a day; yet this is to be understood as *angular motion*,—motion in a small orbit—and therefore embracing a great number of *degrees*, and but comparatively few miles.

APOGEE.

PERIGEE.

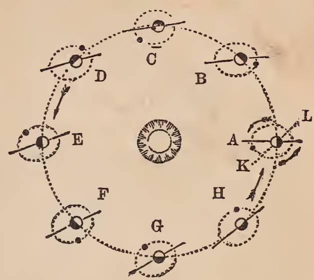
409. The point in the Moon's orbit nearest the Earth is called *Perigee*, from the Greek *peri*, about, and *ge*, the earth. The point most distant is called *Apogee*, from *apo*, from, and *ge*, the earth. These two points are also called the *apsides* of her orbit ; and a line joining them, the *line of the apsides.*

See the Moon in apogee and perigee in the cut. The singular of apsides is *apsis*.

410. The line of the apsides of the Moon's orbit is not fixed in the ecliptic, but revolves slowly around the ecliptic,

408. The Moon's distance? Daily motion in orbit? How many degrees? 409. Perigee and Apogee? Derivation? What other name for these two points? What is the *line* of the apsides? 410. Is this line stationary? What motion? Its period of revolution?

MOTION OF THE APSIDES.



from west to east, in the period of about nine years.

In the adjoining cut, an attempt is made to represent this motion. At A, the line of the apsides points directly to the right and left; but at B, C, and D, it is seen changing its direction, till at E the change is very perceptible when compared with A. But the same ratio of change continues; and at the end of a year, when the Earth reaches A again, the line of the apsides is found to have revolved eastward to the dotted line I K, or about 40°. In nine years the aphelion point near A will have made a complete revolution, and returned to its original position.

411. The line of the Moon's nodes is also in revolution; but it retrogrades or falls back *westward*, making the circuit of the ecliptic once in about nineteen years.

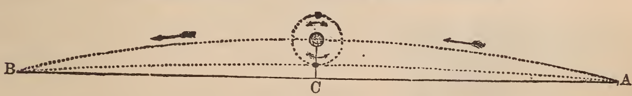
412. Though her orbit is an ellipse, with respect to the Earth, it is, in reality, an irregular curve, always *concave toward the Sun*, and crossing the Earth's orbit every 13° nearly.

If the Earth stood still in her orbit, the Moon would describe just such a path in the ecliptic as she describes with respect to the Earth.

If the Earth moved but slowly on her way, the Moon would actually retrograde on the ecliptic at the time of her change, and would cross her own path at every revolution, as shown in the adjoining figure. But as the Earth advances some 46,000,000 of miles, or near 100 times the diameter of the Moon's orbit, during a single lunation, it is evident that the Moon's orbit never can return into itself, or retrograde, as here represented.

That the lunar orbit is always concave toward the Sun, may be demonstrated by the above diagram.

THE MOON'S ORBIT ALWAYS CONCAVE TOWARD THE SUN.



Let the upper curve line A B represent an arc of the Earth's orbit, equal to that passed through by the Earth during half a lunation. Now the radius and arc being known, it is found that the chord A B must pass more than 400,000 miles within the Earth. But as the Moon departs only 240,000 from the Earth, as shown in the figure, it follows that she must describe the curve denoted by the middle line, which is concave toward the Sun.

This subject may be still further illustrated by the following cut:

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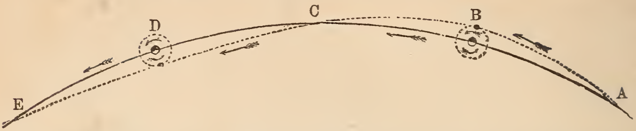
411. How with the line of the Moon's nodes? 412. What is the actual form of the Moon's orbit? How if the Earth stood still? How if she moved but slowly? How is the Moon's orbit demonstrated to be always concave towards the Sun?

THE MOON'S PATH DURING A COMPLETE LUNATION.



Here the plain line represents the Earth's orbit, and the dotted one that of the Moon. At A the Moon crosses the Earth's track 240,000 miles *behind* her. She gains on the Earth, till in seven days she passes her at B as a *Full Moon*. Continuing to gain on the Earth, she crosses her orbit at C, 240,000 miles *ahead* of her, being then at her *Third Quarter*. From this point the Earth gains upon the Moon, till seven days afterward she overtakes her at D as a *New Moon*. From D to E the Earth continues to gain, till at E the Moon crosses 240,000 *behind* the Earth, as she had done four weeks before at A. Thus the Moon winds her way along, first within and then without the Earth; always gaining upon us when outside of our orbit, and falling behind us when within it.

The small circles in the cut represent the Moon's orbit with respect to the Earth, which is as regular *to us* as if the Earth had no revolution around the Sun.

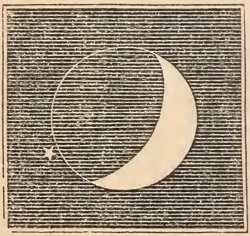
413. The moon never retrogrades on the ecliptic, or returns into her own path again; but is always advancing with the Earth, at the rate of not less than 65,700 miles per hour.

MOON'S PATH.

The Moon's orbitual velocity, with respect to the Earth, is about 2300 miles per hour. When outside the Earth, as at B, in the last figure, she *gains* 2300 miles per hour, which added to the Earth's velocity, would give 70,300 miles as the hourly velocity of the Moon. When *within* the Earth's orbit, as at D, she *loses* 2300 miles per hour, which, substracted from 68,000 miles (the Earth's hourly velocity), would leave 65,700 miles as the slowest motion of the Moon in space, even when she is falling behind the Earth.

Could we look down perpendicularly upon the ecliptic, and see the paths of the Earth and Moon, we should see the latter pursuing her serpentine course, first within and then outside our globe, somewhat as represented by the dotted line in the annexed figure. Her path, however, would be concave toward the Sun, as shown on the preceding page, and not convex, as we were obliged to represent it here in so small a diagram.

414. In her journeyings eastward, the Moon often seems to run over and obscure the distant planets and stars. This phenomenon is called an *occultation*.

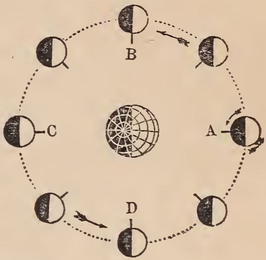


The adjoining cut represents the new Moon as just about to obscure a distant star, by passing between us and it. In 1850, she occulted Jupiter for three revolutions in succession—viz., Jan. 30th, Feb. 27th, and March 26th. Through a telescope, the Moon is seen to be constantly obscuring stars that are invisible to the naked eye. They disappear behind the Moon's eastern limb, and in a short time reappear from behind her western; thus distinctly exhibiting her eastward motion.

413. Does she ever retrograde on the ecliptic? What is her slowest motion? How demonstrated? 414. What is an *occultation*? Remarks respecting this phenomenon?

415. The Moon revolves once on her axis exactly in the time that she performs her revolution around the Earth. This is evident from her always presenting the same side to the Earth; for if she had no rotation upon an axis, every part of her surface would be presented to a spectator on the Earth, in the course of her synodical revolution. It follows, then, that there is but *one day and night in her year*, containing, both together, 29 days, 12 hours, 44 minutes, and 3 seconds.

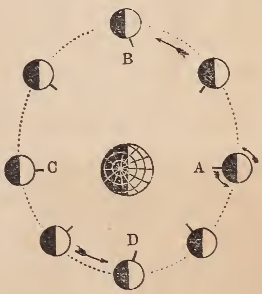
MOON'S REVOLUTION.



Suppose a monument erected upon the Moon's surface, so as to point toward the Earth at *New Moon*, as represented at A. From the Earth it would appear in the Moon's center. Now if the Moon so revolve upon her axis, in the direction of the arrows, as to keep the pillar pointing directly toward the Earth, as shown at A, B, C, and D, and the intermediate points, she must make just one revolution on her axis during her periodic revolution. At A, the pillar points *from* the *Sun*, and at C *toward* him: showing that, in going half-way round the Earth, she has performed half a revolution upon her axis.

416. Though the Moon always presents nearly the same hemisphere toward the Earth, it is not always *precisely* the same. Owing to the ellipticity of her orbit, and the consequent inequality of her angular velocity, she appears to *roll* a little on her axis, first one way and then the other—thus alternately revealing and hiding new territory, as it were, on her eastern and western limbs. This rolling motion east and west is called her *libration in longitude.*

MOON'S LIBRATION.



The accompanying cut will illustrate the subject of the Moon's librations in longitude.

From A around to C, the angular motion is *slower* than the average, and the diurnal motion gains upon it, so that the pillar points *west* of the Earth, and we see more of the *eastern* limb of the moon.

From C to A, again, the Moon advances *faster* than a mean rate, and *gains* upon the diurnal revolution; so that the pillar points *east* of the Earth, and we see more of the Moon's *western* limb. Thus she seems to librate or roll, first one way and then the other, during every periodic revolution.

At B, we see most of her eastern limb; and at D, most of her western.

417. The axis of the Moon is inclined to the plane of her orbit only about one and a half degrees (1° 30′ 10.8″). But this

415. How often does the Moon revolve on her axis? How is it known? What follows from this fact? 416. What are the Moon's librations? In *Longitude?* 417. In *Latitude?*

slight inclination enables us to see first one pole and then the other, in her revolution around the Earth. These slight rolling motions are called her *librations in latitude*

As the inclination of the Earth's axis brings first one pole and then the other toward the *Sun*, and produces the seasons, so the inclination of the Moon's axis brings first one pole and then the other in view from the Earth. But as her inclination is only 1½°, the libration in latitude is very slight.

418. As the Moon turns on her axis only as she moves around the Earth, it is plain that the inhabitants of one half of the lunar world are totally deprived of the sight of the Earth, unless they travel to the opposite hemisphere. This we may presume they will do, were it only to view so sublime a spectacle ; for it is certain that from the Moon the Earth appears *ten times larger* than any other body in the universe.

419. As the Moon enlightens the Earth, by reflecting the light of the Sun, so likewise the Earth illuminates the Moon, exhibiting to her the same phases that she does to us, only in a contrary order. And, as the surface of the Earth is 13 times as large as the surface of the Moon, the Earth, when full to the Moon, will appear 13 times as large as the full Moon does to us. That side of the Moon, therefore, which is towards the Earth, may be said to have no darkness at all, the Earth constantly shining upon it with extraordinary splendor when the Sun is absent ; it therefore enjoys successively two weeks of illumination from the Sun, and two weeks of earth-light from the Earth. The other side of the Moon has alternately a fortnight's light, and a fortnight's darkness.

420. As the Earth revolves on its axis, the several continents, seas, and islands, appear to the lunar inhabitants like so many spots of different forms and brightness, alternately moving over its surface, being more or less brilliant, as they are seen through intervening clouds. By these spots, the lunarians can not only determine the period of the Earth's rotation, just as we do that of the Sun, but they may also find the longitude of their places, as we find the latitude of ours.

421. As the full Moon always happens when the Moon is directly opposite the Sun, all the full moons in our *winter*, must happen when the Moon is on the *north* side of the equinoctial,

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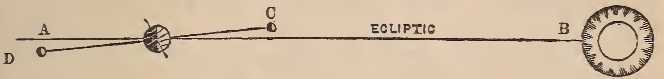
418. Can all the Lunarians see the Earth? How large must she appear from the Moon? 419. What said of her light and phases? How, then, are the two hemispheres of the Moon enlightened? 420. How must the Earth appear to the Lunarians, and what may they infer from the motion of the spots seen on her surface? 421. Where is the Moon at the *full* in winter? In summer? Why? What result as to moonlight at the poles?

because *then* the Sun is on the *south* side of it ; consequently, at the north pole of the Earth, there will be a fortnight's moonlight and a fortnight's darkness by turns, for a period of six months, and the same will be the fact during the Sun's absence the other six months, at the south pole.

422. The plane of the Moon's orbit is very near that of the ecliptic. It departs from the latter only about $5\frac{1}{8}°$ ($5° 8' 48''$.)

INCLINATION OF THE MOON'S ORBIT TO THE PLANE OF THE ECLIPTIC.



Let the line A B represent the plane of the Earth's orbit, and the line joining the Moon at C and D would represent the inclination of the Moon's orbit to that of the Earth. At C the Moon would be *within* the Earth's orbit, and at D exterior to it; and it would be *Full Moon* at D, and *New Moon* at C.

423. The Moon's axis being inclined only about $1\frac{1}{2}°$ to her orbit, she can have no sensible diversity of seasons ; from which we may infer, that her atmosphere is mild and uniform. The quantity of light which we derive from the Moon when full, is at least 300,000 times less than that of the Sun.

This is Monsieur Bouquer's inference, from his experiments, as stated by La Place, in his work, p. 42. The result of Dr. Wollaston's computations was different. Professor Leslie makes the light of the Moon 150,000 times less than that of the Sun; it was formerly reckoned 100,000 times less.

424. The Moon, though apparently as large as the Sun, is the smallest of all the heavenly bodies that are visible to the naked eye. Her diameter is but 2162 miles ; consequently her surface is 13 times less than that of the Earth, and her bulk 49 times less. It would require 70,000,000 of such bodies to equal the volume of the Sun. The reason why she appears as large as the Sun, when, in truth, she is so much less, is because she is 400 times nearer to us than the Sun.

425. When viewed through a good telescope, the Moon presents a most wonderful and interesting aspect. Besides the large dark spots, which are visible to the naked eye, we perceive extensive valleys, shelving rocks, and long ridges of elevated mountains, projecting their shadows on the plains below. Single mountains occasionally rise to a great height, while circular hollows more than *three miles* deep, seem excavated in the plains.

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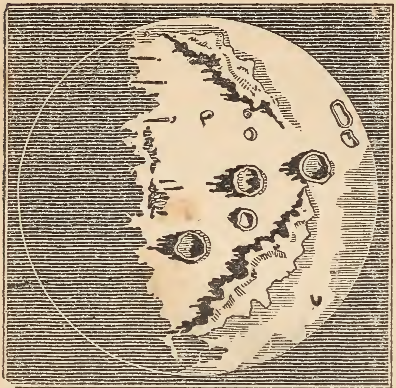
422. How is the Moon's orbit situated with respect to the ecliptic? 423. What is the inclination of the Moon's axis, and what effect has it on her seasons and atmosphere? What is the amount of light derived from the Moon as compared with the Sun, and is there any difference of opinion on this point? 424. What said of the *apparent* and *real* diameters of the Moon? Compared with the Earth? The Sun? Why, then, *appear* as large as he does? 425. How does she appear through a telescope?

TELESCOPIC VIEW OF THE MOON.



Specimens of these *shadows* may be seen in the cut, projecting to the left. Bright points of light, or, in other words, the illuminated tops of mountains, may also be seen near the terminator, in the dark portion. The writer has often watched them, and seen them enlarge more and more, as the Sun arose upon the side of the Moon toward us, and enlightened the sides of her mountains.

The shadows are always projected in a direction opposite the Sun, or towards the dark side of the moon; and as her eastern limb is dark from the change to the full, and her western from the full to the change, of course the direction of the shadows must be reversed.

Suppose a person stationed at a distance directly over the Andes. Before the Sun arose, he would see the tallest peaks enlightened; and as he arose, the long shadows of the mountains would extend to the *west*. At noon, however, little or no shadow would be visible; but at sunset, they would again be seen stretching away to the *east*. This is precisely the change that is seen to take place with the lunar shadows, except that the *time* required is a lunar day, equal to about 15 of our days, instead of one of our days of 12 hours.

426. The Moon's mountain scenery bears a striking resemblance to the towering sublimity and terrific ruggedness of the Alpine regions, or of the Apennines, after which some of her mountains have been named, and of the Cordilleras of our own continent. Huge masses of rock rising precipitously from the plains, lift their peaked summits to an immense height in the air, while shapeless crags hang over their projecting sides, and seem on the eve of being precipitated into the tremendous chasm below.

Around the base of these frightful eminences, are strewed numerous loose and unconnected fragments, which time seems to have detached from their parent mass; and when we examine the rents and ravines which accompany the overhanging cliffs, the beholder expects every moment that they are to be torn from their base, and that the process of destructive separation which he had only contemplated in its effects, is about to be exhibited before him in all its reality.

427. The range of mountains called the Apennines, which traverses a portion of the Moon's disc from northeast to southwest, and of which some parts are visible to the naked eye, rises

426. What said of the Moon's mountain scenery? 427. Of the Apennines in particular?

with a precipitous and craggy front from the level of the *Mare Imbrium*, or Sea of Showers. In this extensive range are several ridges whose summits have a perpendicular elevation of four miles, and more; and though they often descend to a much lower level, they present an inaccessible barrier on the northeast, while on the southwest they sink in gentle declivity to the plains.

428. There is one remarkable feature in the Moon's surface which bears no analogy to anything observable on the Earth. This is the circular cavities which appear in every part of her disc. Some of these immense caverns are nearly four miles deep, and forty miles in diameter. They are the most numerous in the southwestern part. As they reflect the Sun's rays more copiously, they render this part of her surface more brilliant than any other. They present to us nearly the same appearance as our Earth might be supposed to present to the Moon if all our great lakes and seas were dried up.

429. The number of remarkable spots on the Moon, whose latitude and longitude have been accurately determined, exceeds 200. The number of seas and lakes, as they were formerly considered, whose length and breadth are known, is between 20 and 30; while the number of peaks and mountains, whose perpendicular elevation varies from a fourth of a mile to five miles in height, and whose bases are from one to seventy miles in length is not less than one hundred and fifty.

Graphical views of these natural appearances, accompanied with minute and familiar descriptions, constitute what is called *Selenography*, from two Greek words, which mean the same thing in regard to the Moon, as *Geography* does in regard to the Earth.

430. An idea of some of these scenes may be formed by conceiving a plane of about 100 miles in circumference, encircled by a range of mountains, of various forms, three miles in perpendicular height, and having a mountain near the center, whose top reaches a mile and a half above the level of the plain. From the top of this central mountain, the whole plain, with all its scenery, would be distinctly visible, and the view would be bounded only by a lofty amphitheatre of mountains, rearing their summits to the sky.

431. The bright spots of the Moon are the mountainous regions; while the dark spots are the plains, or more level parts of her surface. There may be rivers or small lakes on this

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428. What remarkable feature of the Moon's surface noticed? 429. What number of remarkable spots? Of "seas or lakes?" Of mountains? What is *Selenography?* 430. How conceive justly of the lunar scenery? 431. What are the brightest spots on

planet; but it is generally thought, by astronomers of the present day, that there are no seas or large collections of water, as was formerly supposed. Some of these mountains and deep valleys are visible to the naked eye; and many more are visible through a telescope of but moderate powers.

432. A telescope which magnifies only 100 times will show a spot on the Moon's surface, whose diameter is 1223 yards; and one which magnifies a thousand times, will enable us to perceive any enlightened object on her surface whose dimensions are only 122 yards, which does not much exceed the dimensions of some of our public edifices, as for instance, the Capitol at Washington, or St. Paul's Cathedral. Some years since, Professor Frauenhofer, of Munich, announced that he had discovered a lunar edifice, resembling a *fortification*, together with *several lines of road*. The celebrated astronomer Schroeter, conjectures the existence of a great city on the east side of the Moon, a little north of her equator, an extensive canal in another place, and fields of vegetation in another.

CHAPTER V.

SOLAR AND LUNAR ECLIPSES.

433. Of all the phenomena of the heavens, there are none which engage the attention of mankind more than eclipses of the Sun and Moon; and to those who are unacquainted with astronomy, nothing appears more wonderful than the accuracy with which they can be predicted. In the early ages of antiquity, they were regarded as alarming deviations from the established laws of nature, presaging great public calamities, and other tokens of the divine displeasure.

In China, the prediction and observance of eclipses are made a matter of state policy, in order to operate upon the fears of the ignorant, and impose on them a superstitious regard for the occult wisdom of their rulers. In Mexico, the natives fast and afflict themselves, during eclipses, under an apprehension that the Great Spirit is in deep sufferance. Some of the northern tribes of Indians have imagined that the Moon had been wounded in a quarrel; and others, that she was about to be swallowed by a huge fish.

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the Moon's surface? The dark ones? 432. How small objects may be seen on the Moon's surface? What announcement by Frauenhofer? Conjecture of Schroeter? 433. Subject of Chapter V.? Remark respecting eclipses? How regarded by the ancients? In China? Mexico? By northern Indians? Anecdote of Columbus?

It was by availing himself of these superstitious notions, that Columbus, when shipwrecked on the island of Jamaica, extricated himself and crew from a most embarrassing condition. Being driven to great distress for want of provisions, and the natives refusing him any assistance, when all hope seemed to be cut off, he bethought himself of their superstition in regard to eclipses. Having assembled the principal men of the island, he remonstrated against their inhumanity, as being offensive to the Great Spirit: and told them that a great plague was even then ready to fall upon them, and as a token of it, they would that night see the Moon hide her face in anger, and put on a dreadfully dark and threatening aspect. This artifice had the desired effect; for the eclipse had no sooner begun, than the frightened barbarians came running with all kinds of provisions, and throwing themselves at the feet of Columbus, implored his forgiveness.—*Almagest, vol. I.*, 55 *c. v.* 2.

434. An eclipse of the Sun takes place, when the dark body of the Moon, passing directly between the Earth and the Sun, intercepts his light. This can happen only at the instant of *new* moon, or when the Moon is in conjunction; for it is only then that she passes between us and the Sun.

An eclipse of the Moon takes place when the dark body of the Earth, coming between her and the Sun, intercepts his light, and throws a shadow on the Moon. This can happen only at the time of *full* moon, or when the Moon is in opposition; for it is only then that the Earth is between her and the Sun.

435. As every planet belonging to the solar system, both primary and secondary, derives its light from the Sun, it must cast a shadow towards that part of the heavens which is opposite to the Sun. If the Sun and planet were both of the same magnitude, the form of the shadow cast by the planet, would be that of a cylinder, and of the same diameter as the Sun or planet.

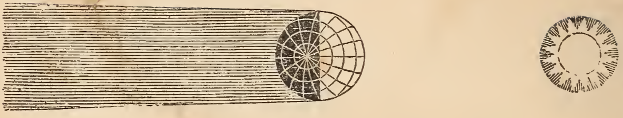
CYLINDRICAL SHADOW.

Here the Sun and planet are represented as *of the same size*, and the shadow of the latter is in the form of a *cylinder*.

436. If the planet were *larger* than the Sun, the shadow would continually diverge, and grow larger and larger; but as the Sun is much larger than any of the planets, the shadows which they cast must converge to a point in the form of a cone, the length of which will be proportional to the size and distance of the planet from the Sun.

434. When do *solar* eclipses occur? Why only then? Lunar? Why only at *full moon?* 435. Do all the planets cast shadows? Suppose the Sun and planet were *of the same size*, what would be the form of their shadows? 436. What if the planet was largest? How as they are smaller than the Sun? How is the length of the shadow modified by the *distance* of the planet from the Sun?

DIVERGING SHADOW.



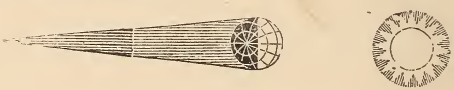
In this cut, the *opaque body is the larger*, and the shadow projected from it *diverges*, or grows more broad as the distance from the planet increases.

If the opaque body is *smaller* than the luminous one, the shadow *converges* to a point.

CONVERGING SHADOW.

Here *the luminous body is the larger*, and the shadow converges to a point, and takes the form of a *cone*.

The opaque body being smaller than the luminous one, the *length* of its shadow will be modified by its *distance*, as in the following:



Here, also, the luminous body is the larger, and both precisely of the same size as in the cut preceding; but being placed *nearer* each other, the shadow is shown to be considerably shorter.

437. All the planets, both primaries and secondaries, cast shadows in a direction opposite the Sun (see cut on next page). The form and length of these shadows depend upon the comparative magnitude of the Sun and planet, and their distance from each other. If the Sun and a planet were of the same size, the shadow of the planet would be in the form of a *cylinder*, whatever its distance. If the planet was *larger* than the Sun, the shadow would *diverge*, as we proceed from the planet off into space; and the nearer the Sun, the more divergent the shadow would be. But as the planets are all much *smaller* than the Sun, the shadows all *converge* to a point, and take the form of a *cone;* and the nearer to the Sun, the shorter their shadows.

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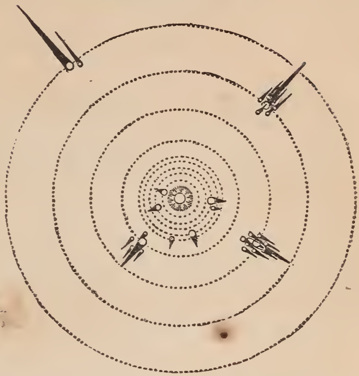
437. Why have the largest and most distant planets the longest shadows? Do any of the primary planets eclipse each other?

SHADOWS OF THE PLANETS.



These principles are partly illustrated in the adjoining cut. The planets nearest the Sun have comparatively short shadows, while those more remote extend to a great distance. No primary, however, casts a shadow long enough to reach the next exterior planet.

The magnitude of the Sun is such, that the shadow cast by each of the primary planets always converges to a point before it reaches any other planet; so that not one of the primary planets can eclipse another. The shadow of any planet which is accompanied by Satellites, may, on certain occasions, eclipse its satellites; but it is not long enough to eclipse any other body. The shadow of a satellite or Moon, may also, on certain occasions, fall on the primary, and eclipse it.

438. When the Sun is at his *greatest* distance from the Earth, and the Moon at her *least* distance, her shadow is sufficiently long to reach the Earth, and extend 19,000 miles beyond. When the Sun is at his *least* distance from the Earth, and the Moon at her *greatest*, her shadow will not reach the Earth's surface by 20,000 miles. So that when the Sun and Moon are at their *mean* distances, the cone of the Moon's shadow will terminate a little before it reaches the Earth's surface.

In the former case, if a conjunction take place when the center of the Moon comes in a direct line between the centers of the Sun and Earth, the dark shadow of the Moon will fall centrally upon the Earth, and cover a circular area of 175 miles in diameter. To all places lying within this dark spot, the Sun will be totally eclipsed, as illustrated by the figure.

439. Eclipses of the Sun must always happen at *New Moon*, and those of the Moon at *Full Moon*. The reason of this is, that the Moon can never be between us and the Sun, to eclipse him, except at the time of her change, or New Moon; and she can never get into the Earth's shadow, to be eclipsed herself, except when she is in opposition to the Sun, and it is Full Moon.

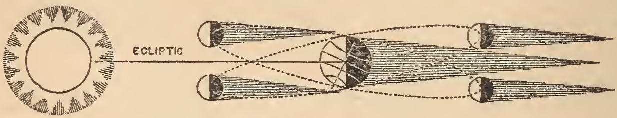
440. If the Moon's orbit lay exactly in the plane of the ecliptic, she would eclipse the Sun at every *change*, and be eclipsed herself at every *full;* but as her orbit departs from the ecliptic over 5° (422), she may pass either above or below the Sun at

438. What is the length of the Moon's shadow when she is nearest the Earth and farthest from the Sun? What when nearest the Sun and farthest from the Earth? What when the Sun and Moon are at their mean distances? 439. At what time of the Moon do solar eclipses always occur? Lunar? Why? 440. Why not two solar and

the time of her change, or above or below the Earth's shadow at the time of her full.

NEW AND FULL MOONS WITHOUT ECLIPSES.

Shadow above the Earth. Above the Earth's shadow.



Shadow below the Earth. Below the Earth's shadow.

Let the line joining the Earth and the Sun represent the plane of the ecliptic. Now as the orbit of the Moon departs from this plane about 5° 9′, she may appear either *above* or *below* the Sun at New Moon, as represented in the figure, and her shadow may fall above the north pole or below the south. At such times, then, there can be no solar eclipse.

On the right, the Moon is shown at her full, both above and below the Earth's shadow, in which case there can be no lunar eclipse.

441. As the Moon passes from one of her nodes to the other in 173 days, there is just this period between two successive eclipses of the Sun, or of the Moon. In whatever time of the year, then, we have eclipses at either node, we may be sure that in 173 days afterwards, we shall have eclipses at the other node.

As the Moon's nodes fall back, or retrograde in the ecliptic, at the rate of 19⅓° every year, they will complete a backward revolution entirely around the ecliptic to the same point again, in 18 years, 225 days; in which time there would always be a regular period of eclipses, if any complete number of lunations were finished without a remainder. But this never happens; for if both the Sun and Moon should start from a line of conjunction with either of the nodes in any point of the ecliptic, the Sun would perform 18 annual revolutions and 222° of another, while the Moon would perform 230 lunations, and 85° of another, before the node would come around to the same point of the ecliptic again; so that the Sun would then be 138° from the node, and the Moon 85° from the Sun.

But after 223 lunations, or 18 years, 11 days, 7 hours, 42 minutes, and 31 seconds, the Sun, Moon, and Earth, will return so nearly in the same position with respect to each other, that there will be a *regular return of the same eclipses for many ages.* This grand period was discovered by the Chaldeans, and by them called *Saros.* If, therefore, to the mean time of any eclipse, either of the Sun or Moon, we add the Chaldean period of 18 years and 11 days, we shall have the return of the same eclipse. This mode of predicting eclipses will hold good for a thousand years. In this period there are usually 70 eclipses; 41 of the Sun and 29 of the Moon.

442. The *diameter* of the Earth's shadow, at the distance of the Moon, is nearly three times as large as the diameter of the Moon; and the *length* of the Earth's shadow is nearly four times as great as the distance of the Moon; exceeding it in the same ratio that the diameter of the Earth does the diameter of the Moon, which is as 3.663 to 1.

443. The number of eclipses in any one year, cannot be less than two, nor more than seven. In the former case, they will

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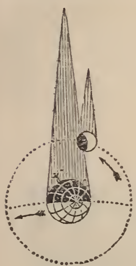
two lunar eclipses every lunar month? 441. How often may eclipses occur at opposite nodes? What cycle of eclipses described? Number of eclipses in this cycle? 442. What is the *diameter* of the Earth's shadow at the distance of the Moon? 443. What number of eclipses may occur in any one year? If but two, what will they be?

both be of the Sun ; and in the latter, there will be five of the Sun, and two of the Moon—those of the Moon will be total. There are sometimes six ; but the usual number is four : two of the Sun, and two of the Moon.

The cause of this variety is thus accounted for. Although the Sun usually passes by both nodes only once in a year, he may pass the same node again a little before the end of the year. In consequence of the retrograde motion of the Moon's nodes, he will come to either of them 173 days after passing the other. He may, therefore, return to the same node in about 346 days, having thus passed one node *twice*, and the other *once*, making each time, at each, an eclipse of both the Sun and the Moon, or *six* in all. And since 12 lunations, or 354 days from the *first* eclipse, in the *beginning* of the year, leave room for another New Moon before the close of the year, and since this New Moon may fall within the ecliptic limit, it is possible for the Sun to be eclipsed again. Thus there may be *seven* eclipses in the same year.

444. Eclipses of the Sun always come on from the west, and pass over eastward ; while eclipses of the Moon come on from the east, and pass over westward. This is a necessary result of the eastward motion of the Moon in her orbit.

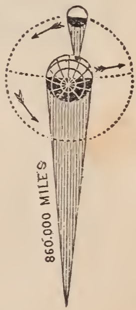
LUNAR ECLIPSE.



SOLAR ECLIPSE.

In the right hand cut, the Moon is seen revolving eastward, throwing her shadow upon the Earth, and hiding the western limb of the Sun. In some instances, however, when the eclipse is very slight, it may first appear on the *northern* or *southern* limb of the Sun—that is, the upper or lower side; but even then its *direction* must be from west to east. It will also be obvious from this figure, that the *shadow* of the Moon upon the Earth must also traverse her surface from west to east; consequently the eclipse will be visible earlier in the west than in the east.

On the left, the Moon is seen striking into the Earth's shadow from the west, and having her eastern limb first obscured. By holding the book up south of him, the student will see at once why the revolution of the Moon eastward must cause a solar eclipse to proceed from west to east, and a lunar eclipse from east to west. To locate objects and motions correctly, the student should generally imagine himself looking to the south, as we are situated north of the equinoctial. The student should bear in mind that nearly all the cuts in the book are drawn to represent a view from northern latitude upon the Earth. Hence, by holding the book up *south* of him, the cuts will generally afford an accurate illustration both of the positions and motions of the bodies represented.



445. The time which elapses between two successive changes of the Moon is called a *Lunation*, which, at a mean rate, is about

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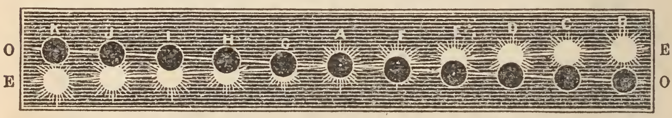
If seven? What is the usual number? Can you explain the *cause* of this variety? 444. What is the direction of a solar eclipse? A lunar? Why this difference? 445. What is a *lunation?* What would be the effect if the solar and lunar months were equal? What result from the existing inequality?

$29\frac{1}{2}$ days. If 12 lunar months were exactly equal to the 12 solar months, the Moon's nodes would always occupy the same points in the ecliptic, and all eclipses would happen in the same months of the year, as is the case with the transits of Mercury and Venus : but, in 12 lunations, or lunar months, there are only 354 days ; and in this time the Moon has passed through both her nodes, but has not quite accomplished her revolution around the Sun ; the consequence is, that the Moon's nodes fall back in the ecliptic at the rate of about $19\frac{1}{3}°$ annually ; so that the eclipses happen sooner every year by about 19 days.

446. Eclipses can never take place, except when the Moon is near the ecliptic ; or, in other words, at or near one of her nodes. At all other times, she passes above or below the Sun, and also above or below the Earth's shadow. It is not necessary that she should be *exactly* at her node, in order that an eclipse occur. If she is within 17° of her node, at the time of her change, she will eclipse the Sun ; and if within 12° of her node at her full, she will strike into the Earth's shadow, and be more or less eclipsed. These distances are called, respectively, the solar and lunar *ecliptic limits.*

This subject may be understood by consulting the following figure.

THE MOON CHANGING AT DIFFERENT DISTANCES FROM HER NODES.



Let the line E E represent the ecliptic, and the line O O the plane of the Moon's orbit. The light globes are the Sun, and the dark ones the Moon, which may be imagined as much nearer the student ; hence their apparent diameter is the same.

Let the point A represent the node of the Moon's orbit. Now if the change occur when the Moon is at B, she will pass *below* the Sun. If when at C, she will just touch his lower limb. At C, she will eclipse him a little, and so on to A ; at which point, if the change occurs, the eclipse would be central, and probably total.

If the Moon was at G, H, I, or J, in her orbit, when the change occurred, she would eclipse the upper or northern limb of the Sun, according to her distance from her node at the time ; but if she was at K, she would pass above the Sun, and would not eclipse him at all. The points C and J will represent the *Solar Ecliptic Limits.*

The mean ecliptic limit for the Sun is $16\frac{1}{2}°$ on each side of the node ; the mean ecliptic limit for the Moon is $10\frac{1}{2}°$ on each side of the node. In the former case, then, there are 33 degrees about each node, making, in all, 66° out of 360°, in which eclipses of the Sun may happen ; in the latter case there are 21° about each node, making, in all, 42° out of 360° in which eclipses of the Moon usually occur. The proportion of the solar to the lunar eclipses, therefore, is as 66 to 42, or as 11 to 7. Yet, there are more visible eclipses of the Moon, at any given place, than of the Sun ; because a lunar eclipse is visible to a whole hemisphere, a solar eclipse only to a small portion of it.

447. All parts of a planet's shadow are not alike dense. The

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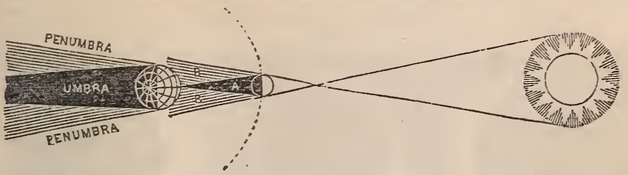
446. Where must the Moon be, with respect to the ecliptic and her nodes, in order to an eclipse? What meant by *ecliptic limits?* Name the distance of each, respectively, from the node. Illustrate. 447. What is the *umbra* of the Earth or Moon? The

darkest portion is called the *umbra*, and the partial shadow the *penumbra.*

UMBRA AND PENUMBRA OF THE EARTH AND MOON.



Penumbra is from the Latin *pene*, almost, and *umbra*, a shadow. In this cut, the Earth's umbra and penumbra will be readily found by the lettering; while A is the umbra, and B B the penumbra, of the Moon. The latter is more broad than it should be, owing to the nearness of the Sun in the cut, as it never extends to much over half the Earth's diameter. The student will see at once that solar eclipses can be total only to persons within the umbra; while to all on which the penumbra falls, a portion of the Sun's disc will be obscured.

448. The average *length* of the Earth's umbra is about 860,000 miles; and its *breadth*, at the distance of the Moon, is about 6000 miles, or three times the Moon's diameter.

As both the Earth and Moon revolve in elliptical orbits, both the above estimates are subject to variations. The length of the Earth's umbra varies from 842,217 to 871,262 miles; and its diameter, where the moon passes it, varies from 5235 to 6365 miles.

449. The average length of the Moon's umbra is about 239,000 miles. It varies from 221,148 to 252,638 miles, according to the Moon's distance from the Sun. Its greatest diameter, at the distance of the Earth, is 170 miles; but the *penumbra* may cover a space on the Earth's surface 4393 miles in diameter.

When the Moon but just touches the limb of the Sun, or the umbra of the Earth, it is called an *appulse* (see C and J in the cut on the opposite page).

450. A *partial* eclipse is one in which only part of the Sun or Moon is obscured. A solar eclipse is partial to all places outside the umbra; but within the umbra, where the whole disc is obscured, the eclipse is said to be *total.* A *central* eclipse is one taking place when the Moon is exactly at one of her nodes. If *lunar*, it is *total*, as the Earth's umbra is always broad enough, at the Moon's distance, if centrally passed, to obscure her whole disc. But a solar eclipse may be *central* and not *total*, as the Moon is not always of sufficient apparent diameter to cover the

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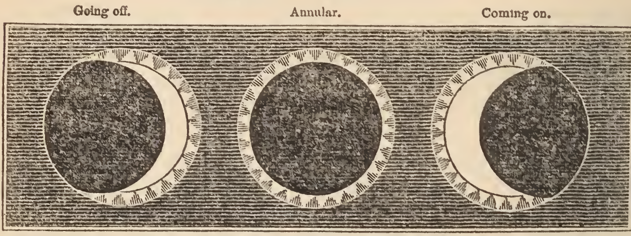
penumbra? Derivation? Within which are solar eclipses total? 448. The average length of the Earth's shadow? Breadth at the Moon's distance? Do they vary? Why? 449. Average length of the Moon's umbra? Does it vary? Why? Greatest diameter at the Earth's surface? Of penumbra? What is an *appulse?* 450. A *partial* eclipse? A *total?* A *central?* Are all central eclipses total? Why not? What called then? Why?

whole disc of the Sun. In that case, the eclipse would be *annular* (from *annulus*, a ring), because the Moon only hides the center of the Sun, and leaves a bright ring unobscured.

PROGRESS OF A CENTRAL ECLIPSE.



451. It has already been shown that the apparent magnitudes of bodies vary as their distances vary; and as both the Earth and Moon revolve in elliptical orbits, it follows that the Moon and Sun must both vary in their respective apparent magnitudes. Hence some central eclipses of the Sun are total, while others are partial and annular.

TOTAL AND ANNULAR ECLIPSES OF THE SUN

At A, the Earth is at her *aphelion*, and the Sun being at his most distant point, will have his *least* apparent magnitude. At the same time, the Moon is in *perigee*, and appears *larger* than usual. If, therefore, she pass centrally over the Sun's disc, the eclipse will be *total*.

At B, this order is reversed. The Earth is at her *perihelion*, and the Moon in *apogee;* so that the Sun appears *larger*, and the Moon *smaller* than usual. If, then, a central eclipse occur under these circumstances, the Moon will not be large enough to eclipse the whole of the Sun, but will leave a ring, apparently around herself, unobscured. Such eclipse will be *annular*.

452. The greatest possible duration of the annular appearance of a solar eclipse, is 12 minutes and 24 seconds; and the greatest possible time during which the Sun can be totally eclipsed, to any part of the world, is 7 minutes and 58 seconds. The Moon may continue totally eclipsed for one hour and three quarters.

553. As the solar ecliptic's limits are further from the Moon's nodes than the lunar, it results that we have more eclipses of the Sun than of the Moon. There may be seven in all in one

451. Why are some central eclipses total, and others partial and annular? 452. How long may an *annular* eclipse continue? A *total* eclipse of the Sun? Of the Moon? 453. Which kind of eclipses is most frequent? Why? The greatest number in a year?

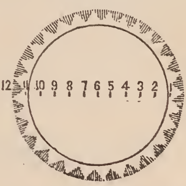
year, viz., five solar and two lunar ; but the most usual number is four. There can never be less than two in a year ; in which case, both must be of the Sun. Eclipses both of the Sun and Moon recur in nearly the same order, and at the same intervals, at the expiration of a cycle of 223 lunations, or 18 years of 365 days and 15 hours. This cycle is called the *Period of the Eclipses.* At the expiration of this time, the Sun and the Moon's nodes will sustain the same relation to each other as at the beginning, and a new cycle of eclipses begins.

454. In a total eclipse of the Sun, the heavens are shrouded in darkness, the planets and stars become visible, the temperature declines, the animal tribes become agitated, and a general gloom overspreads the landscape. Such were the effects of the great eclipse of 1806. In a lunar eclipse, the Moon begins to lose a portion of her light and grows dim, as she enters the Earth's penumbra, till at length she comes in contact with the umbra, and the real eclipse begins.

455. In order to measure and record the extent of eclipses, the apparent diameters of the Sun and Moon are divided into twelve equal parts, called *digits;* and in predicting eclipses, astronomers usually state which "*limb*" of the body is to be eclipsed—the southern or northern—the time of the first contact, of the nearest approach of centers, direction, and number of digits eclipsed.

FIVE DIGITS ECLIPSED.

TWELVE DIGITS.



456. The last *annular* eclipse visible in the United States, occurred May 26, 1854. The next total eclipse of the Sun will be August 7, 1869.

Some of the ancients, and all barbarous nations, formerly regarded eclipses with amazement and fear, as supernatural events, indicating the displeasure of the gods. Columbus is said

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How many of each? Least number, and which? Usual number? What said of the *order* of eclipses? Time of cycle? 454. Describe the effects of a total eclipse of the Sun. The process of a lunar eclipse? 455. How are eclipses measured and recorded? 456. When the next annular eclipse visible in this country? The next total? How have to have made a very happy use of this superstition, as already stated on a previous page. (Art. 433.)

457. Eclipses can be calculated with the greatest precision, not only for a few years to come, but for centuries and ages either past or to come. This fact demonstrates the truth of the Copernican theory, and illustrates the *order* and *stability* that everywhere reign throughout the planetary regions.

The following is a list of all the solar eclipses that will be visible in Europe and America during the remainder of the present century. To those which will be visible in New England, the number of digits is annexed.

Year.	Month.	Day and hour.	Digits.	Year.	Month.	Day and hour.	Digits.
1858,	Mar.	15 6 14 A. M.	1⅔	1878,	July	29 4 56 P. M.	7⅓
1859,	July	29 5 32 P. M.	2½	1879,	July	19 2 0 A. M.	
1860,	July	18 7 23 A. M.	6⅓	1880,	Dec.	31 7 30 A. M.	5½
1861,	Dec.	31 7 30 A. M.	4½	1882,	May	17 1 0 A. M.	
1863,	May	17 1 0 P. M.		1885,	Mar.	16 0 35 A. M.	6½
1865,	Oct.	19 9 10 A. M.	3⅔	1886,	Aug.	29 6 30 A. M.	0¼
1866,	Oct.	8 11 12 A. M.	0	1887,	Aug.	18 10 0 P. M.	
1867,	Mar.	6 3 0 A. M.		1890,	June	17 3 0 A. M.	
1868,	Feb.	23 10 0 A. M.		1891,	June	6 0 0 Mer.	
1869,	Aug.	7 5 21 A. M.	10¼	1892,	Oct.	20 0 19 P. M.	8¼
1870,	Dec.	22 6 0 A. M.		1895,	Mar.	26 4 0 A. M.	
1873,	May	26 3 0 A. M.		1896,	Aug.	9 0 0 Mer.	
1874,	Oct.	10 4 0 A. M.		1897,	July	29 9 8 A. M.	4½
1875,	Sept.	29 5 56 A. M.	11½	1899,	June	8 0 0 Mer.	
1876,	Mar.	25 4 11 P. M.	3⅔	1900,	May	28 8 9 A. M.	11

The eclipses of 1869, 1875, and 1900 will be very large. In those of 1858, 1861, 1873, 1875, and 1880, the *Sun will rise eclipsed.*

That of 1875 will be *annular.* The scholar can continue this table, or extend it backwards, by adding or substracting the Chaldean period of 18 years, 11 days, 7 hours, 54 minutes, and 31 seconds.

CHAPTER VI.

PRIMARY PLANETS CONTINUED—MARS AND THE ASTEROIDS.

458. Mars is the first of the exterior planets, its orbit lying immediately without, or *beyond*, that of the Earth, while those of Mercury and Venus are *within.* He appears, to the naked eye, of a fine ruddy complexion ; resembling, in color, and appa-

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the ignorant and superstitious regarded eclipses? 457. What said of the calculation of eclipses? What does this demonstrate and illustrate? 458. Position of Mars' orbit? How does he appear to the naked eye? When most brilliant? When least?

rent magnitude, the star Antares, or Aldebaran, near which it frequently passes. It exhibits its greatest brilliancy about the time that it rises when the Sun sets, and sets when the Sun rises; because it is then nearest the Earth. It is least brilliant when it rises and sets with the Sun; for then it is five times farther removed from us than in the former case.

459. Its distance from the Earth at its nearest approach is about 50,000,000 of miles. Its greatest distance from us is about 240,000,000 of miles. In the former case, it appears nearly 25 times larger than in the latter. When it rises before the Sun, it is our morning star; when it sets after the Sun, it is our evening star.

The distance of all the planets from the Earth, whether they be interior or exterior planets, varies within the limits of the diameters of their orbits; for when a planet is in that point of its orbit which is nearest the Earth, it is evidently nearer by the whole diameter of its orbit, than when it is in the opposite point, on the other side of its orbit. The *apparent diameter* of the planet will also vary for the same reason, and to the same degree.

460. Mars is sometimes seen in opposition to the Sun, and sometimes in superior conjunction with him; sometimes gibbous, but never horned. In conjunction, it is never seen to pass over the Sun's disc, like Mercury and Venus. These prove not only that its orbit is *exterior* to the Earth's orbit, but that it is an opaque body, shining only by the reflection of the Sun.

461. The motion of Mars through the constellations of the zodiac is but little more than *half* as great as that of the Earth; it being generally about 57 days in passing over one sign, which is at the rate of a little more than half a degree each day. Thus, if we know what constellation Mars enters to-day, we may conclude that two months hence it will be in the next constellation; four months hence, in the next; six months, in the next, and so on.

Its mean *sidereal* revolution is performed in 686.9796458 solar days; or in 686 days, 23 hours, 30 minutes, 41.4 seconds. Its *synodical* revolution is performed in 779.936 solar days; or in 779 days, 22 hours, 27 minutes, and 50 seconds.

462. Mars performs his revolution around the Sun in one year and $10\frac{1}{2}$ months, at the distance of 145,000,000 of miles; moving in its orbit at the mean rate of 55,000 miles an hour. Its diurnal rotation on its axis is performed in 24 hours, 39

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459. Its distance from the Earth? What effect upon its apparent magnitude? When morning and evening star? How do the distances of the planets from the Earth vary? Their apparent diameters? 460. Is Mars ever in *opposition* to the Sun? In *conjunction?* Its phases? Does it ever transit the Sun? What do these facts prove? 461. What is his rate of motion through the constellations? What calculation based upon it? 462. His periodic time? Distance from the Sun? Mean rate of motion per hour? Time of rotation on his axis? How does his day compare with ours?

minutes, and $21\frac{1}{2}$ seconds; which makes its day about 44 minutes longer than ours.

463. Its form is that of an oblate spheroid, whose polar diameter is to its equatorial, as 15 is to 16, nearly. Its diameter is 4,222 miles. Its bulk, therefore, is 7 times less than that of the Earth; and being 50,000,000 of miles farther from the Sun, it receives from him only half as much light and heat.

464. The inclination of its axis to the plane of its orbit, is about $28\frac{2}{3}°$. Consequently, its seasons must be very similar to those of the Earth. Indeed, the analogy between Mars and the Earth is greater than the analogy between the Earth and any other planet of the solar system. Their diurnal motion, and of course the length of their days and nights, are nearly the same; the obliquity of their ecliptics, on which the seasons depend, are not very different; and, of all the superior planets, the distance of Mars from the Sun is by far the nearest to that of the Earth; nor is the length of its year greatly different from ours, when compared with the years of Jupiter, Saturn and Uranus.

465. To a spectator on this planet, the Earth will appear alternately, as a morning and evening star; and will exhibit all the phases of the Moon, just as Mercury and Venus do to us; and sometimes like them, will appear to pass over the Sun's disc like a dark round spot. Our Moon will never appear more than *a quarter of a degree* from the Earth, although her distance from it is 240,000 miles. If Mars be attended by a satellite, it is too small to be seen by the most powerful telescopes.

When it is considered that Vesta, the smallest of the asteroids, which is *once and a half* times the distance of Mars from us, and only 269 miles in diameter, is perceivable in the open space, and that without the presence of a more conspicuous body to point it out, we may reasonably conclude that Mars is without a Moon.

466. The progress of Mars in the heavens, and indeed of all the superior planets, will, like Mercury and Venus, sometimes appear direct, sometimes retrograde, and sometimes he will seem stationary. The portion of the ecliptic through which a planet seems to retrograde is called the *Arc of Retrogradation.* The more remote the planet the less the arc, and the longer the time of its retrogression. These retrograde movements and stations, as they appear to a spectator from the Earth, are common to all the planets, and demonstrate the truth of the Copernican system.

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463. Form of Mars? Diameter? Bulk? Light and heat? 464. Inclination of his axis to the plane of his orbit? His seasons? Resemblance to our globe? 465. How would the Earth appear to a spectator upon Mars? Our Moon? Has Mars a satellite? 466. What said of the motions of Mars and the other planets? What constitutes the

RETROGRADE MOTION OF THE EXTERIOR PLANETS.

Suppose the Earth at A, and the planet Neptune at B, he would then appear to be at C, among the stars; but as Neptune moves but a little from B toward F, while the Earth is passing from A to D, Neptune will appear to retrograde from C to E. Whatever Neptune may have moved, however, from B toward F, will go to reduce the amount of apparent retrogression.

It is obvious from this figure, that the more distant an exterior planet is, and the slower it moves, the less will be its arc of retrogradation, and the longer will it be retrograding. Neptune appears to retrograde 180 days, or nearly half the year.

The following table exhibits the *amount of arc* and the *time* of the retrogradation of the principal planets:

	Arc.	Days.
Mercury	13½°	23
Venus	16	42
Mars	16	73
Jupiter	10	121
Saturn	6	139
Uranus	4	151
Neptune	1	180

TELESCOPIC APPEARANCES OF MARS.

The right-hand figure represents Mars as seen at the Cincinnati Observatory, August 5, 1845. On the 30th of the same month he appeared as represented on the left. The *middle view* is from a drawing by Dr. Dick.

467. The telescopic phenomena of Mars afford peculiar interest to astronomers. They behold its disc diversified with numerous irregular and variable spots, and ornamented with zones and belts of varying brilliancy, that form, and disappear, by turns. Zones of intense brightness are to be seen in its polar regions, subject, however, to gradual changes. That of the southern pole is much the most brilliant. Dr. Herschel supposes that they are produced by the reflection of the Sun's light from the frozen regions, and that the melting of these masses of polar ice is the cause of the variation in their magnitude and appearance.

Arc of Retrogradation? What do these motions prove? 467. How does Mars appear through a telescope? Dr. Herschel's opinion of its polar regions? How confirmed in

He was the more confirmed in these opinions by observing that after the exposure of the luminous zone about the north pole to a summer of eight months, it was considerably *decreased*, while that on the south pole, which had been in total darkness during eight months, had considerably *increased*. He observed, farther, that when this spot was most luminous, the disc of Mars did not appear exactly *round*, and that the bright part of its southern limb seemed to be swollen or arched out beyond the proper curve.

468. The extraordinary height and density of the atmosphere of Mars, are supposed to be the cause of the remarkable redness of its light. It has been found, by experiment, that when a beam of white light passes through any colorless transparent medium, its color inclines to red, in proportion to the density of the medium, and the space through which it has traveled. Thus the Sun, Moon, and stars, appear of a reddish color when near the horizon; and every luminous object, seen through a mist, is of a ruddy hue.

This phenomena may be thus explained:—The momentum of the red, or least refrangible rays, being greater than that of the violet, or most refrangible rays, the former will make their way through the resisting medium, while the latter are either reflected or absorbed. The color of the *beam*, therefore, when it reaches the eye, must partake of the color of the least refrangible rays, and this color must increase with the distance. The dim light, therefore, by which Mars is illuminated, having to pass *twice* through its atmosphere before it reaches the Earth, must be deprived of a great proportion of its violet rays, and consequently then be red. Dr. Brewster supposes that the difference of color among the other planets, and even the fixed stars, is owing to the different heights and densities of their atmospheres.

THE ASTEROIDS, OR TELESCOPIC PLANETS.

469. Ascending higher in the solar system, we find, between the orbits of Mars and Jupiter, a cluster of twenty-seven small planets, which present a variety of anomalies that distinguish them from all the older planets of the system. Their names are Flora, Clio, Vesta, Iris, Metis, Eunomia, Psyche, Thetis, Melpomene, Fortuna, Massilia, Lutetia, Calliope, Thalia, Hebe, Parthenope, Irene, Egeria, Astræa, Juno, Ceres, Pallas, and Hygeia. These, and four others whose names have not yet been announced, have all been discovered during the present century.

470. The scientific Bode entertained the opinion, that the planetary distances, above Mercury, formed a geometrical series, each exterior orbit being double the distance of its next interior one, from the Sun; a fact which obtains with remarkable exactness between Jupiter, Saturn, and Uranus. But this law seemed to be interrupted between Mars and Jupiter. Hence he inferred, that there was a planet wanting in that interval; which is now

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this opi ion? 468. Supposed cause of the ruddy *color* of Mars? Philosophical explanation? Dr. Brewster's opinion? 469. Position and number of the asteroids? When discover d? 470. Bode's theory? What seeming interruption? What conclusion?

happily supplied by the discovery of the numerous *star-form* planets, occupying the very space where the unexplained vacancy presented a strong objection to his theory.

According to Bode, the distances of the planets may be expressed nearly as follows: the Earth's distance from the Sun being 10.

Mercury	4	=	4	Asteroids	$4+3\times2^3$	=	28
Venus	$4+3\times1$	=	7	Jupiter	$4+3\times2^4$	=	52
The Earth	$4+3\times2$	=	10	Saturn	$4+3\times2^5$	=	100
Mars	$4+3\times2^2$	=	16	Herschel	$4+3\times2^6$	=	196

Comparing these values with the actual mean distances of the planets from the Sun, we cannot but remark the near agreement, and can scarcely hesitate to pronounce that the respective distances of the planets from the Sun, were assigned according to a law, although we are entirely ignorant of the exact law, and of the reason for that law.—*Brinkley's Elements, p.* 89.

471. The Asteroids are *much smaller* in size than the older planets—they all revolve *at nearly the same distances* from the Sun, and perform their revolutions in *nearly the same periods*—their orbits are much *more eccentric*, and have a *much greater inclination* to the ecliptic—and what is altogether singular, except in the case of comets—some of their orbits *cross each other;* so that there is even a *possibility* that two of these bodies may, some time, in the course of their revolutions, come into collision.

The orbit of Vesta is so eccentric, that she is sometimes farther from the Sun than either Ceres, Pallas, or Juno, although her mean distance is many millions of miles less than theirs. The orbit of Vesta crosses the orbits of several other asteroids, in two opposite points.

The student should here refer to the Figures, Map I. of the Atlas, and verify such of these particulars as are there represented. It would be well for the teacher to require him to observe particularly the positions of their orbits, and to state their different degrees of inclination to the plane of the ecliptic.

472. From these and other circumstances, many eminent astronomers are of opinion, that these twenty-seven planets are the fragments of a large celestial body which once revolved between Mars and Jupiter, and which burst asunder by some tremendous convulsion, or some external violence. The discovery of Ceres, by Piazzi, on the first day of the present century, drew the attention of all the astronomers of the age to that region of the sky, and every inch of it was minutely explored. The consequence was, that in the year following, Dr. Olbers, of Bremen, announced to the world the discovery of Pallas, situated not many degrees from Ceres, and very much resembling it in size.

How substantially justified? 471. Size of the asteroids? Distance from the Sun? Periodic time? Forms of their orbits? Position with respect to the ecliptic? What other singularity in their orbits? What remarkable facts respecting the orbit of Vesta? 472. What conclusion has been drawn from these facts? Progress of discovery?

473. From this discovery, Dr. Olbers first conceived the idea that these bodies might be the fragments of a former world ; and if so, that other portions of it might be found either in the same neighborhood, or else, having diverged from the same point, "they ought to have two common points of reunion, or two nodes in opposite regions of the heavens through which all the planetary fragments must sooner or later pass."

474. One of these nodes he found to be in the constellation Virgo, and the opposite one in the Whale ; and it is a remarkable coincidence that it was in the neighborhood of the latter constellation that Mr. Harding discovered the planet Juno. In order, therefore, to detect the remaining fragments, if any existed, Dr. Olbers examined, three times every year, all the small stars in Virgo and the Whale ; and it was actually in the constellation Virgo, that he discovered the planet Vesta. Since that time, twenty-three additional asteroids have been discovered, and it is not unlikely that still additional fragments of a similar description will hereafter be discovered.

Dr. Brewster attributes the fall of meteoric stones to the smaller fragments of these bodies happening to come within the sphere of the Earth's attraction.

Meteoric stones, or what are generally termed *aerolites*, are stones which sometimes fall from the upper regions of the atmosphere upon the Earth. The substance of which they are composed, is, for the most part, *metallic ;* but the ore of which it consists is not to be found *in the same constituent proportions* in any known substance upon the Earth. Their fall is generally preceded by a luminous appearance, a hissing noise, and a loud explosion ; and when found immediately after their descent, they are always hot, and usually covered with a black crust, indicating a state of exterior fusion.

Their size varies from that of small fragments of inconsiderable weight to that of the most ponderous masses. They have been found to weigh from 300 pounds to several tons ; and they have descended to the earth with a force sufficient to bury them many feet under the surface.

Some have supposed that they are projected from volcanoes in the Moon ; others that they proceed from volcanoes on the Earth ; while others imagine that they are generated in the regions of the atmosphere ; but the truth probably is not yet ascertained. In some instances, these stones have penetrated through the roofs of houses, and proved destructive to the inhabitants.

If we carefully compute the force of gravity in the Moon, we shall find that if a body were projected from her surface with a momentum that would cause it to move at the rate of 8200 feet in the first second of time, and in the direction of a line joining the centers of the Earth and Moon, it would not fall again to the surface of the Moon ; but would become a satellite to the Earth. Such an impulse might, indeed, cause it, even after many revolutions, to fall to the earth. The fall, therefore, of these stones, from the air, may be accounted for in this manner.

Mr. Harte calculates, that even a velocity of 6000 feet in a second, would be sufficient to carry a body projected from the surface of the Moon beyond the power of her attraction. If so, a projectile force three times greater than that of a cannon, would carry a a body from the Moon, beyond the point of equal attraction, and cause it to reach the Earth. A force equal to this is often exerted by our volcanoes, and by subterranean steam. Hence, there is no impossibility in the supposition of their coming from the Moon.

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473. Theory of Dr. Olbers? 474. Where did he find these nodes? What remarkable coincidence? Dr. Olbers' efforts? Discoveries since? Dr. Brewster's idea respecting meteoric stones? What are meteoric stones? Circumstances of their fall? Size and weight? Supposed origin? Could they have fallen from the Moon? What computations?

475. Vesta appears like a star of the 5th or 6th magnitude, shining with a pure steady radiance, and is the only one of the asteroids which can be discerned by the naked eye.

Juno revolves around the Sun in 4 years, 4½ months, at the mean distance of 254,000,000 of miles, moving in her orbit at the rate of 41,000 miles an hour. Her diameter is estimated at 1393 miles. This would make her magnitude 183 times less than the Earth's. The light and heat which she receives from the Sun is seven times less than that received by the Earth.

The eccentricity of her orbit is so great, that her greatest distance from the Sun is nearly double her least distance ; so that, when she is in her *perihelion*, she is nearer the Sun by 130,000,000 of miles, than when she is in her *aphelion*. This great eccentricity has a corresponding effect upon her rate of motion ; for being so much nearer, and therefore so much more powerfully attracted by the Sun at one time than at another, she moves through that half of her orbit which is nearest the Sun, in one-half of the time that she occupies in completing the other half.

According to Schroeter, the diameter of Juno is 1425 miles ; and she is surrounded by an atmosphere more dense than that of any of the other planets. Schroeter also remarks that the variation in her brilliancy is chiefly owing to certain changes in the density of her atmosphere ; at the same time, he thinks it not improbable that these changes may arise from a diurnal revolution on her axis.

476. Ceres revolves about the Sun in 4 years, 7⅓ months, at the mean distance of 263,500,000 of miles, moving in her orbit at the rate of 41,000 miles an hour. Her diameter is estimated at 1582 miles, which makes her magnitude 125 times less than the Earth's. The intensity of the light and heat which she receives from the Sun is about 7½ times less than that of those received by the Earth.

Ceres shines with a ruddy color, and appears to be only about the size of a star of the 8th magnitude. Consequently she is never seen by the naked eye. She is surrounded by a species of cloudy or nebulous light, which gives her somewhat the appearance of a comet, forming, according to Schroeter, an atmosphere 675 miles in height.

Ceres, as has been said, was the first discovered of the asteroids. At her discovery, astronomers congratulated themselves upon the harmony of the system being restored. They had long wanted a planet to fill up the great void between Mars and Jupiter, in order to make the system complete in their own eyes ; but the successive discoveries of

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475. What is the appearance of Vesta ? Juno's period ? Distance from the Sun ? Rate of motion ? Diameter ? Relative magnitude ? Light and heat ? Eccentricity of orbit ? Effect upon her orbitual motion ? 476. Ceres' period and mean distance ? Rate of motion ? Diameter ? Relative magnitude ? Light and heat ? Color and apparent size ? How seen ? What said of her atmosphere ? Her discovery ?

Pallas and Juno again introduced confusion, and presented a difficulty which they were unable to solve, till Dr. Olbers suggested the idea that these small anomalous bodies were merely the fragments of a larger planet, which had been exploded by some mighty convulsion. Among the most able and decided advocates of this hypothesis, is Dr. Brewster, of Edinburgh.

477. PALLAS performs her revolution around the Sun in 4 years, 7⅔ months, at the mean distance of 264,000,000 of miles, moving in her orbit at the rate of 41,000 miles an hour. Her diameter is estimated at 2025 miles, which is but little less than that of our Moon. It is a singular and very remarkable phenomenon in the solar system, that two planets (Ceres and Pallas), nearly of the same size, should be situated at equal distances from the Sun, revolve about him in the same period, and in orbits that intersect each other. The difference in the respective distances of Ceres and Pallas is less than a million of miles. The difference in their sidereal revolutions, according to some astronomers, is but a single day.

The calculation of the latitude and longitude of the asteroids is a labor of extreme difficulty, requiring more than 400 equations to reduce their anomalous perturbations to the true place. This arises from the want of auxiliary tables, and from the fact that the elements of the star-form planets are very imperfectly determined. Whether any of the asteroids has a rotation on its axis, remains to be ascertained.

The following Table contains most that is known of the asteroids to the present date (1855):

TABLE OF THE INTRRIOR PLANETS AND ASTEROIDS.

NAMES.	Mean distance from the Sun in miles.	Period of revolution round the Sun in days.	When discovered.	By whom discovered.	Where discovered.
Mercury	209,160,265	1,193	Oct. 18, 1847	Hind	London.
Venus	221,813,220	1,303	Sept. 13, 1850	Hind	London.
The Earth	224,302,695	1,325	March 29, 1807	Olbers	Bremen.
Mars	226,159,280	1,341	Aug. 13, 1847	Hind	London.
Flora	226,632,665	1,345	April 26, 1848	Graham	Markree.
Clio	227,946,800	1,357	July 29, 1851	Gasparis	Naples.
Vesta	....	....	March 17, 1852	Gasparis	Naples.
Iris	....	....	April 17, 1852	Luther	Bilk, Ger
Metis	....	....	June 24, 1852	Hind	London.
Eunomia	....	....	Aug. 22, 1852	Hind	London.
Psyche	....	....	Sept. 21, 1852	Charconac	Marseilles.
Thetis	....	....	Nov. 15, 1852	Goldschmit	Paris.
Melpomene	....	....	Nov. 16, 1852	Hind	London.
Fortuna	....	....	....	....	....
Massilia	....	....	April 5, 1853	Gasparis	Naples.
Lutetia	....	....	May 5, 1853	Luther	Bilk, Ger.
Calliope	230,449,670	1,379	July 1, 1847	Hencke	Driessen.
Thalia	232,829,135	1,401	May 13, 1850	Gasparis	Naples.
New planet	242,468,785	1,518	May 20, 1850	Hind	London.
New planet	243,206,650	1,492	Nov. 2, 1850	Gasparis	Naples.
Hebe	244,818,565	1,511	Dec. 8, 1845	Hencke	Driessen.
Parthenope	253,728,615	1,594	Sept. 1, 1804	Harding	Lilienthal.
Irene	262,964,845	1,682	Jan. 1, 1801	Piazzi	Palermo.
Egeria	263,421,510	1,686	March 28, 1802	Olbers	Bremen.
Astræa	299,255,700	2,042	April 12, 1849	Gasparis	Naples.

477. Periodic revolution of Pallas? Mean distance from the Sun? Rate of motion? Diameter? What remarkable phenomenon mentioned?

CHAPTER VII.

PRIMARY PLANETS—JUPITER AND SATURN.

478. JUPITER is the largest of all the planets belonging to the solar system. It may be readily distinguished from the fixed stars, by its peculiar splendor and magnitude ; appearing to the naked eye almost as resplendent as Venus, although it is more than seven times her distance from the Sun.

When his right ascension is less than that of the Sun, he is our morning star, and appears in the eastern hemisphere before the Sun rises ; when greater, he is our evening star, and lingers in the western hemisphere after the Sun sets.

Nothing can be easier than to trace Jupiter among the constellations of the zodiac ; for in whatever constellation he is seen to-day, one year hence he will be seen equally advanced in the *next* constellation ; two years hence, in the next ; three years hence, in the next, and so on ; being just a year, at a mean rate, in passing over one constellation.

The exact mean motion of Jupiter in its orbit, is about one-twelfth of a degree in a day ; which amounts to only 30° 20′ 32″ in a year.

For 12 years to come, he will, at a mean rate, pass through the constellations of the zodiac, as follows :

1856, Aquarius.	1860, Gemini.	1864, Libra.
1857, Pisces.	1861, Cancer.	1865, Scorpio.
1858, Aries.	1862, Leo.	1866, Sagittarius.
1859, Taurus.	1863, Virgo.	1867, Capricornus.

479. Jupiter is the next planet in the solar system above the asteroids, and performs his annual revolution around the Sun in nearly 12 of our years, at the mean distance of 495,000,000 of miles ; moving in his orbit at the rate of 30,000 miles an hour.

The exact period of Jupiter's sidereal revolution is 11 years, 10 months, 17 days, 14 hours, 21 minutes, 25½ seconds. His exact mean distance from the Sun is 495,533,837 miles ; consequently, the exact rate of his motion in his orbit, is 29,943 miles per hour.

480. He revolves on an axis, which is nearly perpendicular to the plane of his orbit, in 9 hours, 55 minutes, and 50 seconds ; so that his year contains 10,471 days and nights ; each about 5 hours long.

His form is that of an oblate spheroid, whose polar diameter

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478. Comparative size of Jupiter ? How distinguished from the fixed stars ? When morning star, &c. ? Is he easily traced ? 479. His position in the system ? His periodic time ? Distance from the Sun ? Rate of motion ? 480. Time of diurnal revolution ? Position of axis ? Length of his days ? Number in his year ? His form ? Cause of his oblateness ? Difference of equatorial and polar diameters ? The Earth ?

is to its equatorial, as 13 to 14. He is therefore considerably more flattened at the poles than any of the other planets, except Saturn. This is caused by his rapid rotation on his axis ; for it is an universal law that the equatorial parts of every body, revolving on an axis, will be swollen out, in proportion to the density of the body, and the rapidity of its motion.

The difference between the polar and equatorial diameters of Jupiter, exceeds 6000 miles. The difference between the polar and equatorial diameters of the Earth, is only 26 miles. Jupiter, even on the most careless view through a good telescope, appears to be oval ; the longer diameter being parallel to the direction of his belts, which are also parallel to the ecliptic.

481. By this rapid whirl on its axis, his equatorial inhabitants are carried around at the rate of 26,554 miles an hour ; which is 1600 miles farther than the equatorial inhabitants of the Earth are carried, by its diurnal motion, in *twenty-four hours.*

The true *mean* diameter of Jupiter is 86,255 miles ; which is nearly 11 times greater than the Earth's. His volume is, therefore, about *thirteen hundred* times larger than that of the Earth. (*For magnitude as compared with that of the Earth, see Map I.*) On account of his great distance from the Sun, the degree of light and heat which he receives from it is 27 times *less* than that received by the Earth.

When Jupiter is in conjunction, he rises, sets, and comes to the meridian with the Sun; but is never observed to make a transit, or pass over the Sun's disc ; when in opposition, he rises when the Sun sets, sets when the Sun rises, and comes to the meridian at midnight, which never happens in the case of an *interior* planet. This proves that Jupiter revolves in an orbit which is *exterior* to that of the Earth.

482. As the variety in the seasons of a planet, and in the length of its days and nights, depends upon the inclination of its axis to the plane of its orbit, and as the axis of Jupiter has little or no inclination, there can be no difference in his seasons, on the same parallels of latitude, nor any variation in the length of his days and nights. It is not to be understood, however, that *one uniform season* prevails from his equator to his poles ; but that the *same parallels of latitude* on each side of his equator, uniformly enjoy the same season, whatever season it may be.

About his equatorial regions there is perpetual summer ; and at his poles everlasting winter ; but yet equal day and equal night at each. This arrangement seems to have been kindly ordered by the beneficent Creator ; for had his axis been inclined to his orbit, like that of the Earth, his polar winters would have been alternately a dreadful night of *six years' darkness.*

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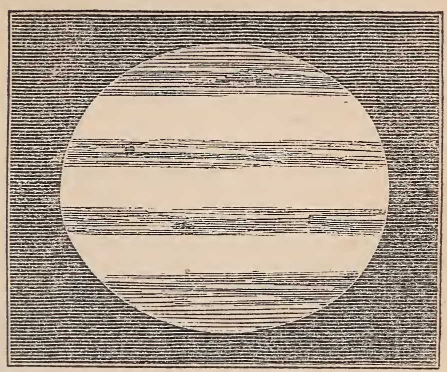
481. Motion at Jupiter's equator? His *mean* diameter? His volume? Light and heat? Does he ever transit the Sun? What proof that his orbit is exterior to that of the Earth? 482. What of the *seasons* of Jupiter? What apparent manifestation of Divine Wisdom?

TELESCOPIC VIEW OF JUPITER.



483. Jupiter, when viewed through a telescope, appears to be surrounded by a number of luminous zones, usually termed *belts*, that frequently extend quite around him. These belts are parallel not only to each other, but, in general, to his equator, which is also nearly parallel to the ecliptic. They are subject, however, to considerable variation, both in breath and number. Sometimes eight have been seen at once; sometimes only one, but more usually three. Dr. Herschel once perceived his whole disc covered with small belts, though they are more usually confined to within 30° of his equator, that is, to a zone 60° in width.

Sometimes these belts continue for months at a time with little or no variation, and sometimes a new belt has been seen to form in a few hours. Sometimes they are interrupted in their length; and at other times, they appear to spread in width, and run into each other, until their breadth exceeds 5000 miles.

484. Bright and dark spots are also frequently to be seen in the belts, which usually disappear with the belts themselves, though not always, for Cassini observed that one occupied the same position more than 40 years. Of the *cause* of these variable appearances, but little is known. They are generally supposed to be nothing more than *atmospherical phenomena*, resulting from, or combined with, the rapid motion of the planet upon its axis.

Different opinions have been entertained by astronomers respecting the cause of these belts and spots. By some they have been regarded as clouds, or as openings in the atmosphere of the planet, while others imagine that they are of a more permanent nature, and are the marks of great physical revolutions, which are perpetually agitating and changing the surface of the planet. The first of these opinions sufficiently explains the variations in the form and magnitude of the *spots*, and the *parallelism* of the belts.

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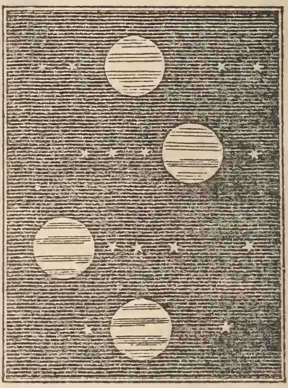
483. How does Jupiter appear through a telescope? Where are his belts usually seen? Their number? Are they permanent? 484. What else seen upon Jupiter's surface? Are *they* permanent? Is the cause of these phenomena well understood? What different opinions?

The spot first observed by Cassini, in 1665, which has both disappeared and reappeared in the same form and position for the space of 43 years, could not possibly be occasioned by any atmospherical variations, but seems evidently to be connected with the surface of the planet. The form of the belt, according to some astronomers, may be accounted for by supposing that the *atmosphere* reflects more light than the *body* of the planet, and that the clouds which float in it, being thrown into parallel strata by the rapidity of its diurnal motion, form regular *insterstices*, through which are seen its opaque body, or any of the permanent spots which may come within the range of the opening.

MOONS OF JUPITER.

485. Jupiter is attended by four satellites or moons They are easily seen with a common spy-glass, appearing like small stars near the primary. (See adjoining cut.) By watching them for a few evenings, they will be seen to change their places, and to occupy different positions. At times, only one or two may be seen, as the others are either between the observer and the planet, or *beyond* the primary, or eclipsed by his shadow.

TELESCOPIC VIEWS OF THE MOONS OF JUPITER.



486. The size of these satellites is about the same as our moon, except the second, which is a trifle less. The first is about the distance of our moon ; and the others, respectively, about two, three, and five times as far off.

COMPARATIVE DISTANCES OF JUPITER'S MOONS

487 Their periods of revolution are from 1 day 18 hours to 17 days, according to their distances. This rapid motion is necessary, in order to counterbalance the powerful centripetal force of the planet, and to keep the satellites from falling to his surface.

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485. How many moons has Jupiter? How seen? Why not all seen at once? 486 Their size? Distances? 487. Periods of Jupiter's satellites? Why so rapid?

The magnitudes, distances, and periods of the moons of Jupiter are as follows:

	Diameter in miles.	Distance.	Periodic times.
1st	2,500	259,000	1 day 18 hours.
2d	2,068	414,000	3 " 12 "
3d	3,377	647,000	7 " 14 "
4th	2,890	1,164,000	17 " 0 "

488. The orbits of Jupiter's moons are all in or near the plane of his equator; and as his orbit nearly coincides with the ecliptic, and his equator with his orbit, it follows that, like our own moon, his satellites revolve near the plane of the ecliptic. On this account, they are sometimes between us and the planet, and sometimes beyond him, and seem to oscillate, like a pendulum, from their greatest elongation on one side to their greatest elongation on the other.

489. Their direction is from west to east, or in the direction their primary revolves, both upon his axis and in his orbit. From the fact that their elongations east and west of Jupiter are nearly the same at every revolution, it is concluded that their orbits are but slightly elliptical. They are supposed to revolve on their respective axis, like our own satellite, the moon, once during every periodic revolution.

490. As these orbits lie near the plane of the ecliptic, they have to pass through his broad shadow when in opposition to the Sun, and be totally eclipsed at every revolution. To this there is but one exception. As the fourth satellite departs about 3° from the plane of Jupiter's orbit, and is quite distant, it sometimes passes *above* or *below* the shadow, and escapes eclipse. But such escapes are not frequent.

These moons are not only often eclipsed, but they often eclipse Jupiter, by throwing their own dark shadows upon his disc. They may be seen like dark round spots traversing it from side to side, causing, wherever that shadow falls, an eclipse of the Sun. Altogether, about forty of these eclipses occur in the system of Jupiter every month.

491. The *immersions* and *emersions* of Jupiter's moons have reference to the phenomena of their being eclipsed. Their *entrance into* the shadow is the *immersion;* and their *coming out of it* the *emersion.*

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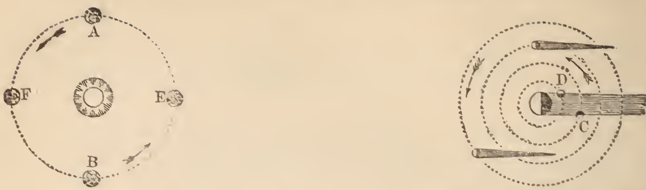
488. How are their orbits situated? How satellites appear to move? 489. Direction of secondaries? Form of orbits? How ascertained? What motion on axis? 490. What said of eclipses? Of fourth satellite? Of solar eclipses upon Jupiter? Number of solar and lunar? 491. What are the *immersions* and *emersions* of Jupiter's moons? Are the immersions and emersions always visible from the Earth? Why not? Illustrate.

ECLIPSES OF JUPITER'S MOONS, EMERSIONS, ETC.



The above is a perpendicular view of the orbits of Jupiter's satellites. His broad shadow is projected in a direction opposite the Sun. At C, the second satellite is suffering an *immersion*, and will soon be totally eclipsed; while at D, the first is in the act of *emersion*, and will soon appear with its wonted brightness. The other satellites are seen to cast their shadows off into space, and are ready in turn to eclipse the Sun, or cut off a portion of his beams from the face of the primary.

If the Earth were at A in the cut, the *immersion*, represented at C, would be invisible; and if at B, the *emersion* at D could not be seen. So, also, if the Earth were exactly at F, neither could be seen; as Jupiter and all his attendants would be directly beyond the Sun, and would be hid from our view.

492. The system of Jupiter may be regarded as a miniature representation of the solar system, and as furnishing triumphant evidence of the truth of the Copernican theory. It may also be regarded as a great *natural clock*, keeping absolute time for the whole world; as the immersions and emersions of his satellites furnish a uniform standard, and, like a vast chronometer hung up in the heavens, enable the mariner to determine his longitude upon the trackless deep.

By long and careful observations upon these satellites, astronomers have been able to construct tables, showing the exact time when each immersion and emersion will take place, at Greenwich Observatory, near London. Now suppose the tables fixed the time for a certain satellite to be eclipsed at 12 o'clock at Greenwich, but we find it to occur at 9 o'clock, for instance, by our local time: this would show that our time was three hours *behind* the time at Greenwich; or, in other words, that we were three hours, or 45°, *west* of Greenwich. If our time was *ahead* of Greenwich time, it would show that we were *east* of that meridian, to the amount of 15° for every hour of variation. But this method of finding the longitude is less used than the "lunar method" (Art. 407), on account of the greater difficulty of making the necessary observations.

493. By observations upon the eclipses of Jupiter's moons, as compared with the tables fixing the time of their occurrence, it was discovered that light had a progressive motion, at the rate of about 200,000 miles per second.

This discovery may be illustrated by again referring to the preceding cut. In the year 1675, it was observed by Roemer, a Danish astronomer, that when the Earth was nearest to Jupiter, as at E, the eclipses of his satellites took place 8 minutes 13 seconds *sooner* than the mean time of the tables; but when the earth was farthest from Jupiter, as at F, the eclipses took place 8 minutes and 13 seconds *later* than the tables predicted, the entire difference being 16 minutes and 26 seconds. This difference of time he ascribed to the progressive motion of light, which he concluded required 16 minutes and 26 seconds to cross the earth's orbit from E to F.

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492. How may the system of Jupiter be regarded? What use of it made in navigation? Illustrate method? Is it much used? 493. What discovery by observing the eclipses of Jupiter's moons? Explain the process?

This progress may be demonstrated as follows :—16m. 26s.=986s. If the radius of the Earth's orbit be 95,000,000 of miles, the diameter must be twice that, or 190,000,000. Divide 190,000,000 miles by 986 seconds, and we have $192,697\frac{379}{439}$ miles as the progress of light in each second. At this rate, light would pass nearly eight times around the globe at every tick of the clock, or nearly 500 times every minute !

494. Jupiter, when seen from his nearest satellite, appears a *thousand times larger* than our Moon does to us, exhibiting on a scale of inconceivable magnificence, the varying forms of a crescent, a half moon, a gibbous phase, and a full moon, every 42 hours.

SATURN.

495. SATURN is situated between the orbits of Jupiter and Uranus, and is distinctly visible to the naked eye. It may be easily distinguished from the fixed stars by its pale, feeble, and steady light. It resembles the star Fomalhaut, both in color and size, differing from it only in the steadiness and uniformity of its light.

From the slowness of its motion in its orbit, the pupil throughout the period of his whole life, may trace its apparent course among the stars, without any danger of mistake. Having once found when it enters a particular constellation, he may easily remember where he is to look for it in any subsequent year; because, at a mean rate, it is just 2½ years in passing over a single sign or constellation.

Saturn's mean daily motion among the stars is only about 2′, the *thirtieth part of a degree.*

496. The mean distance of Saturn from the Sun is nearly double that of Jupiter, being about 909,000,000 of miles. His diameter is about 82,000 miles ; his volume, therefore, is *eleven hundred times* greater than the Earth's. Moving in his orbit at the rate of 22,000 miles an hour, he requires 29½ years to complete his circuit around the Sun : but his diurnal rotation on his axis is accomplished in 10½ hours. His year, therefore, is nearly thirty times as long as ours, while his day is shorter by more than one-half. His year contains about 25,150 of its own days, which are equal to 10,759 of our days.

497. The surface of Saturn, like that of Jupiter, is diversified with belts and dark spots. Dr. Herschel sometimes perceived five belts on his surface ; three of which were dark and two bright. The dark belts have a yellowish tinge, and generally cover a broader zone of the planet than those of Jupiter.

To the inhabitants of Saturn, the Sun appears 90 times less than he appears at the Earth; and they receive from him only one *ninetieth part* as much light and heat. But

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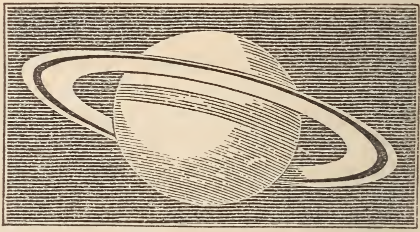
494. How does Jupiter appear from his nearest satellite? 495. Situation of Saturn? How distinguished? How trace? His rate of motion in the heavens? 496. Distance from the Sun? Diameter? Volume? Rate of motion in orbit? Periodic time? Diurnal revolution? Days in his year? 497. Appearance of his surface? Belts? The Sun as seen from Saturn? Light and heat of that planet? Estimated strength of the

it is computed that even the *ninetieth* part of the Sun's light exceeds the illuminating power of 3000 full moons, which would be abundantly sufficient for all the purposes of life.

498. The telescopic appearance of Saturn is unparalleled. It is even more interesting than Jupiter, with all his moons and belts. That which eminently distinguishes this planet from every other in the system, is a magnificent zone or ring, encircling it with perpetual light.

TELESCOPIC VIEW OF SATURN.



The adjoining cut is an excellent representation of Saturn as seen through a telescope. The oblateness of the planet is easily perceptible, and his *shadow* can be seen upon the rings back of the planet. The shadow of the rings may also be seen running across his disc. The writer has often seen the opening between the body of the planet and the interior ring as distinctly as it appears to the student in the cut. Under very powerful telescopes, these rings are found to be again subdivided into an indefinite number of concentric circles, one within the other, though this is considered doubtful by Sir John Herschel.

499. The light of the ring is more brilliant than the planet itself. It turns around its center of motion in the same time that Saturn turns on its axis. When viewed with a good telescope, it is usually found to consist of two concentric rings, divided by a dark band.

It has been ascertained, however, that these rings are again subdivided; the third division was distinctly seen by Prof. Encke, on the 25th of April, 1837, and also by Mr. Lassel, on the 7th of September, 1843, at his observatory near Liverpool, England. Six different rings were seen at Rome, in Italy, on the night of the 29th of May, 1838. And more recent observations by Professor Bond, of Cambridge, have led to the conclusion that, in all probability, these wonderful rings are *fluid!* It is well known that under the most powerful instruments they seem to be almost indefinitely subdivided.

500. As our view of the rings of Saturn is generally an oblique one, they usually appear *elliptical*, and never circular. The ellipse seems to contract for about 7½ years, till it almost entirely disappears, when it begins to expand again, and continues to enlarge for 7½ years, when it reaches its maximum of expansion, and again begins to contract. For fifteen years, the part of the rings *toward* us seems to be *thrown up*, while for the

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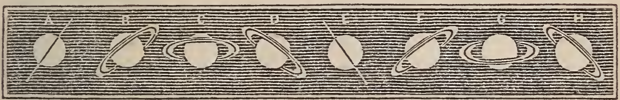
solar radiance? 498. Telescopic appearance of Saturn? For what distinguished? 499. Comparative light of his rings? Time of rotation around the planet? How does it usually appear? What further discoveries? 500. What the general apparent figure of the rings? Why elliptical? What periodic variation of expansion? Of inclination? When nearly invisible?

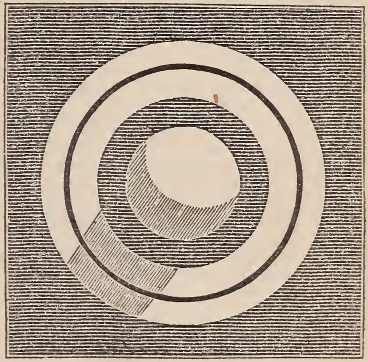
next fifteen it appears to drop *below* the apparent center of the planet; and while shifting from one extreme to the other, the rings become almost invisible, appearing only as a faint line of light running from the planet in opposite directions. The rings vary also in their inclination, sometimes dipping to the right, and at others to the left.

TELESCOPIC PHASES OF THE RINGS OF SATURN.



The above is a good representation of the various inclinations and degrees of expansion of the rings of Saturn, during his periodic journey of 30 years

PERPENDICULAR VIEW OF THE RINGS OF SATURN.



501. The rings of the planet are always directed more or less toward the Earth, and sometimes exactly toward us; so that we never see them perpendicularly, but always either exactly edgewise, or obliquely, as shown in the last figure. Were either pole of the planet exactly toward us, we should then have a perpendicular view of the rings, as shown in the adjoining cut.

502. The various phases of Saturn's rings are explained by the facts that his axis remains parallel to itself (see following cut), with an uniform inclination to the plane of his orbit, which is very near the ecliptic; and as the rings revolve over his equator, and at right angles with his axis, they also remain parallel to themselves. The revolution of the planet about the Earth every 30 years, must therefore bring first one side of the rings to view, and then the other—causing all the variations of expansion, position, and inclination which the rings present.

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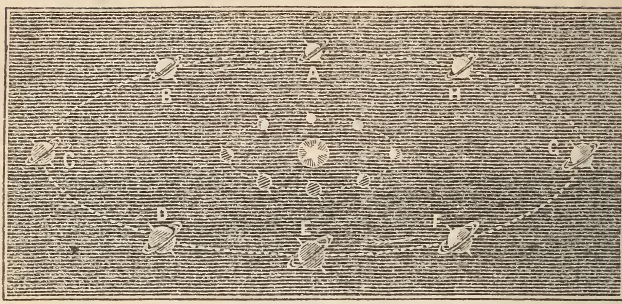
501. How are the rings situated with respect to the Earth? How would they appear if either pole of Saturn were toward us? 502. How are the various phases of Saturn's rings accounted for?

SATURN AT DIFFERENT POINTS IN HIS ORBIT.



Here observe, first, that the axis of Saturn, like those of all the other planets, remains permanent, or *parallel with itself;* and as the rings are in the plane of his equator, and at right angles with his axis, they also must remain parallel to themselves, whatever position the planet may occupy in its orbit.

This being the case, it is obvious that while the planet is passing from A to E, the Sun will shine upon the *under* or *south* side of the rings; and while he passes from E to A again, upon the *upper* or *north* side; and as it requires about 30 years for the planet to traverse these two semicircles, it is plain that the alternate day and night on the rings will be 15 years each.

A and E are the *equinoctial*, and C and G the *solstitial* points in the orbit of Saturn. At A and E the rings are *edgewise* toward the Sun, and also toward the Earth, provided Saturn is in opposition to the Sun. To an observer on the Earth, the rings will seem to expand from A to C, and to contract from C to E. So, also, from E to G, and from G to A. Again: from A to E the front of the rings will appear *above* the planet's center, and from E to A *below* it.

The rings of Saturn were invisible, as rings, from the 22d of April, 1848, to the 19th of January, 1849. He came to his equinox September 7, 1848; from which time to February, 1856, his rings will continue to expand. From that time to June, 1863, they will contract, when he will reach his other equinox at E, and the rings will be invisible. From June, 1863, to September, 1870, they will again expand; and from September, 1870, to March, 1877, they will contract, when he will be at the equinox passed September 7, 1848, or 29½ years before.

The writer has often seen the rings of Saturn in different stages of expansion, and contraction, and *once* when they were almost directly *edgewise* toward the Earth. At that time (January, 1849), they appeared as a bright line of light, as represented at A and E, in the first cut on the preceding page.

503. The dimensions of the rings of Saturn may be stated in round numbers as follows:

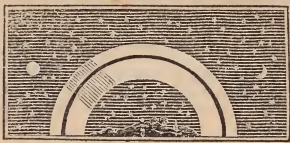
	Miles.
Distance from the body of the planet to the first ring	19,000
Width of interior ring	17,000
Space between the interior and exterior rings	2,000
Width of exterior ring	10,500
Thickness of the rings	100

503. State the distances and dimensions of his rings, beginning at the body of the planet, and passing outward? What additional statistics from Herschel?

In a recent work, entitled "The New Theory of Creation and Deluge," it is predicted that, at some future time, the fluid rings of Saturn may descend and deluge the planet, as ours was deluged in the days of Noah. Sir David Brewster says:—"Mr. Otto Struve and Mr. Bond have lately studied with the great Munich telescope at the Observatory of Pulkoway, the third ring of Saturn, which Mr. Dassels and Mr. Bond discovered to be fluid. These astronomers are of opinion that this fluid ring is not of very recent formation, and that it is not subject to rapid change, and they have come to the extraordinary conclusion that the inner border of the ring has, since the time of Huygens, been gradually approaching the body of Saturn, and that we may expect, sooner or later, perhaps in some dozen of years, to see the rings united with the body of the planet."

504. The rings of Saturn serve as reflectors to reflect the light of the Sun upon his disc, as our Moon reflects the light to the Earth. In his nocturnal sky, they must appear like two gorgeous arches of light, bright as the full moon, and spanning the whole heavens like a stupendous rainbow.

NIGHT SCENE UPON SATURN.



In the annexed cut, the beholder is supposed to be situated some 30° north of the equator of Saturn, and looking directly south. The *shadow* of the planet is seen travelling up the arch as the night advances, while a *New Moon* is shown in the west, and a *Full Moon* in the east at the same time.

505. The two rings united are nearly 13 times as wide as the diameter of the Moon; and the nearest is only $\frac{1}{12}$th as far from the planet as the Moon is from us.

The two rings united are 27,500 miles wide; which ÷ 2160 the moon's diameter $=12\frac{7}{10}$. So 240,000 miles, the Moon's distance ÷ 19,000 the distance of Saturn's interior ring $=12\frac{12}{19}$.

At the distance of only 19,000 miles, our Moon would appear some forty times as large as she does at her present distance. How magnificent and inconceivably grand, then, must these vast rings appear, with a thousand times the Moon's magnitude, and only one-twelfth part of her distance!

506. The periodic time of Saturn being nearly thirty years, his motion eastward among the stars must be very slow, amounting to only 12° a year, or one sign in $2\frac{1}{2}$ years. It will be easy, therefore, having once ascertained his position, to watch his slow progress eastward year after year. Saturn is now (1855) just east of the seven stars.

MOONS OF SATURN.

507. Besides the magnificent rings already described, the telescope reveals *eight satellites* or *moons*, revolving around Saturn. But these are seen only with good instruments, and under favorable circumstances.

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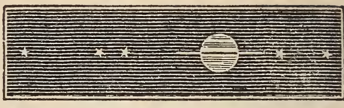
504. What purpose do the rings of Saturn serve? How appear in his evening sky? 505. Width of two rings, as compared with Moon? Distance? Demonstrate both. How would our Moon appear at the distance of Saturn's rings? 506. Eastward motion of Saturn? How traced? 507. Moons of Saturn? How seen? Best time for observing?

SATELLITES OF SATURN.



The best time for observing them is when the planet is at his equinoxes, and his rings are nearly invisible.

In January, 1849, the author saw five of these satellites, as represented in the adjoining cut. The rings appeared only as a line of light extending each way from the planet, and the satellites were in the direction of the line, at different distances, as here represented

508. These satellites all revolve eastward with the rings of the planet, in orbits nearly circular, and, with the exception of the eighth, in the plane of the rings. Their mean distances, respectively, from the planet's center are from 123,000 to 2,366,000 miles ; and their periods from 22 hours to 79 days, according to their distances.

The distances and periods of the satellites of Saturn are as follows :

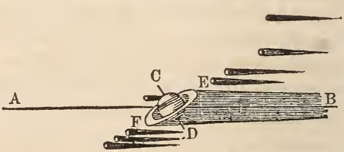
	Distance in miles.	Periodic times.		Distance in miles.	Periodic times.
1st	123,000	0 day 22 hours	5th	351,000	4 days 12 hours.
2d	158,000	1 " 8 "	6th	811,000	15 " 22 "
3d	196,000	1 " 21 "	7th	2,366,000	79 " 7 "
4th	251,000	2 " 17 "			

Of the 8th satellite recently discovered, we have as yet much less knowledge than of its predecessors.

COMPARATIVE DISTANCES OF THE MOONS OF SATURN.

509. The most distant of these satellites is the largest, supposed to be about the size of Mars ; and the remainder grow smaller as they are nearer the primary. They are seldom eclipsed, on account of the great inclination of their orbits to the ecliptic, except twice in thirty years, when the rings are edgewise toward the Sun. The eighth satellite, which has been studied more than all the rest, is known to revolve once upon its axis during every periodic revolution ; from which it is inferred that they all revolve on their respective axis in the same manner.

SYSTEM OF SATURN—NO ECLIPSES.



Let the line A B represent the plane of the planet's orbit, C D his axis, and E F the plane of his rings. The satellites being in the plane of the rings will revolve *around* the shadow of the primary, instead of passing through it, and being eclipsed.

At the time of his equinoxes, however, when the rings are turned toward the Sun (see A and E, cut, page 242) they must be in the center of the shadow on

508. The revolutions? Shape and position of their orbits? Distances from their primary? 509. Comparative size?

the opposite side; and the moons, revolving in the plane of the rings, must pass through the shadow at every revolution. The eighth, however, may sometimes escape, on account of his departure from the plane of the rings, as shown in the cut.

510. The theory of the satellites of Saturn is less perfect than than that of the satellites of Jupiter. The difficulty of observing their eclipses, and of measuring their elongations from their primary, have prevented astronomers from determining, with their usual precision, their mean distances and revolutions. But of this we are certain: there is no planet in the solar system, whose firmament presents such a variety of splendid and magnificent objects as that of Saturn.

The various aspects of the seven moons, one rising above the horizon, while another is setting, and a third approaching to the meridian; one entering into an eclipse, and another emerging from one; one appearing as a crescent, and another with a gibbous phase; and sometimes the whole of them shining in the same hemisphere, in one bright assemblage! The majestic motion of the rings—at one time illuminating the sky with their splendor, and eclipsing the stars; at another, casting a deep shade over certain regions of the planet, and unveiling to view the wonders of the starry firmament, are scenes worthy of the majesty of the Divine Being to unfold, and of rational creatures to contemplate.

Such displays of Wisdom and Omnipotence, lead us to conclude that the numerous splendid objects connected with this planet, were not created merely to shed their luster on naked rocks and barren sands; but that an immense population of intelligent beings is placed in those regions, to enjoy the bounty, and adore the goodness, of their great Creator.

CHAPTER VIII.

PRIMARY PLANETS.—URANUS AND NEPTUNE.

511. Uranus is the next planet in order from the Sun, beyond or above Saturn. To the naked eye, it appears like a star of only the 6th or 7th magnitude, and of a pale, bluish white; but it can seldom be seen, except in a very fine, clear night, and in the absence of the Moon. Through a telescope, he exhibits a small, round, uniformly illuminated disc, without rings, belts, or discernible spots. His apparent diameter is about 4″, from which he never varies much, owing to the smallness of our orbit in comparison with his own.

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510. Is the system of Saturn well understood? Why not? Of what are we sure? What scenes must it present? To what conclusion must these phenomena lead us? 511. Position and appearance of Uranus? Through a telescope?

Sir John Herschel says he is without discernible spots, and yet in his tables he lays down the time of the planet's rotation (which could only be ascertained by the rotation of spots upon the planet's disc), at 9½ hours. This time is probably given on the authority of Schroeter, and is marked as doubtful by Dr. Herschel.

512. The motion of Uranus in longitude is still slower than that of Saturn. It moves over but one degree of its orbit in 85 days; hence he will be *seven years* in passing over one sign or constellation. His periodic time being 84 years 27 days, his eastward motion can amount to only about 4° 17′ in a whole year. To detect this motion requires instruments and close observations. At this date (1855), Uranus has passed over about $\frac{7}{8}$ of his orbit, since his discovery in 1781; and in 1865 will have traversed the whole circuit of the heavens, and reached the point where Herschel found him 84 years before.

It is remarkable that this body was observed as far back as 1690. It was seen three times by Flamstead, once by Bradley, once by Mayer, and eleven times by Lemonnier, who registered it among the stars; but not one of them suspected it to be a planet.

513. The inequalities in the motions of Jupiter and Saturn, which could not be accounted for from the mutual attractions of these planets, led astronomers to suppose that there existed another planet beyond the orbit of Saturn, by whose action these irregularities were produced. This conjecture was confirmed March 13th, 1781, when Dr. Herschel discovered the *motions* of this body, and thus proved it to be a planet.

514. The mean distance of Uranus from the Sun is 1,828,000,000 of miles; more than twice the mean distance of Saturn. His sidereal revolution is performed in 84 years and 1 month, and his motion in his orbit is 15,600 miles an hour. He is supposed to have a rotation on his axis, in common with the other planets; but astronomers have not yet been able to obtain any ocular proof of such a motion

515. His diameter is estimated at 34,000 miles; which would make his volume more than 80 times larger than the Earth's. To his inhabitants, the Sun appears only the $\frac{1}{368}$ part as large as he does to us; and of course they receive from him only that small proportion of light and heat. It may be shown, however, that the $\frac{1}{368}$ part of the Sun's light exceeds the illuminating power of 800 full moons. This, added to the light they must receive from their six satellites, will render their days and nights far from cheerless.

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512. His motion in longitude? Periodic time? Angular motion per year? How far has he been traced since his discovery? When complete his revolution? Was he ever seen previous to 1781? By whom? Why are they not the *discoverers*, then? 513. Was his existence suspected previous to 1781? What ground for the suspicion? How proved to be a planet? 514. Mean distance? Sidereal revolution? Hourly motion in orbit? Rotation on axis? 515. Diameter? Volume? Light and heat? Use of satellites?

516. Uranus is attended by six moons or satellites, which revolve about him in different periods, and at various distances. Four of them were discovered by Sir William Herschel, and two by his sister, Miss Caroline Herschel. It is possible that others remain yet to be discovered.

Sir William Herschel reckoned six, though no other observer has confirmed this opinion; and even his son, Sir John Herschel, seems to consider the existence of six satellites quite doubtful. After mentioning the two most conspicuous, he says: "Of the remaining four, whose existence, though announced with considerable confidence by their original discoverer, could hardly be regarded as fully demonstrated, two only have been hitherto re-observed."—*Outlines of Astronomy*, *Article* 551. The two that he regarded as doubtful he supposed would be found, if at all, in orbits exterior to those of the other four.

The distance from the planet and periodic times of the satellites of Uranus, respectively, are as follows:

	Dist. in miles.	Periodic Times.					Dist. in miles.	Periodic Times.			
		D.	H.	M.	S.			D.	H.	M.	S.
1.	224,000	5	21	25	20	4.	390,000	11	10	56	29
2.	296,000	8	16	57	47	5.	777,000	38	01	48	00
3.	340,000	10	23	02	47	6.	1,556,000	107	16	39	56

NEPTUNE.

517. This is the most distant of the primary planets, and in some respects one of the most interesting. It is about 31,000 miles in diameter, is situated at the mean distance of 2,850,000,000 miles from the Sun, and revolves around him in 164 years. So remote is this newly-discovered member of the solar system, that for a body to reach it, moving at railroad speed, or 30 miles an hour, would require more than *twenty thousand years!*

518. The circumstances of the *discovery* of this planet are at once interesting and remarkable. Such is the regularity of the planetary motions, that astronomers are enabled to predict, with great accuracy, their future places in the heavens, and to construct tables, exhibiting their positions for ages to come. Soon after the discovery of Uranus, in 1781, his orbit was computed, and a table constructed for determining his future positions in the heavens, but instead of following the prescribed path, or occupying his estimated positions, he was found to be yielding to some mysterious and unaccountable influence, under which he was gradually leaving his computed orbit, and failing to meet conditions of the tables.

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516. Number of Moons? By whom discovered? Is it certain that Uranus has six satellites? Why doubtful? 517. Distance and diameter of Neptune? Period? How long to pass from the Sun to it at railroad speed? 518. What remarkable circumstances respecting its discovery? Perturbation?

519. At first this discrepancy between the observed and the estimated places of Uranus, was charged upon the *tables*, and a new orbit and new tables were computed, which it was thought could not fail to represent the future places of the planet. But these also seemed to be erroneous, as it was soon discovered that the computed and observed places did not agree, and the difference was becoming greater and greater every year. This was an anomaly in the movements of a planetary body. It was not strange that it should be subject to perturbations, from the attractive influence of the large planets Jupiter and Saturn, as these were known to act upon him, as well as upon each other, and the smaller planets, producing perturbations in their orbits, but all this had been taken into the account in constructing the tables, and still the planet deviated from its prescribed path.

520. To charge the discrepancy to the *tables*, was no longer reasonable, though it was thought perhaps sufficient allowance had not been made, in their computation, for the disturbing influence of Jupiter and Saturn. To determine this question, M. Leverrier, of Paris, undertook a thorough discussion of the subject, and soon ascertained that the disturbing influence upon Uranus of all the known planets, was not sufficient to account for the anomalous perturbations already described, and that they were probably caused by some *unknown planet*, revolving beyond the orbit of Uranus. From the amount and effect of this disturbing influence from an unknown source, the distance, magnitude, and position of the imaginary planet were computed.

521. At this stage of the investigation, Leverrier wrote to his friend, Dr. Galle, of Berlin, requesting him to direct his telescope to that part of the heavens in which his calculations had located the new planet, when lo! there he lay, *a thousand millions of miles beyond the orbit of Uranus*, and yet within less than one degree of the *place* pointed out by Leverrier! This was on the 1st of September, 1846.

522. While M. Leverrier was engaged in his calculations at Paris, Mr. Adams, a young mathematician of Cambridge, England, was discussing the same great problem, and had arrived at similar results even before M. Leverrier, though entirely ignorant of each other's labors or conclusions. This seems to estab-

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519. To what attributed at first? What done to correct? What then? 520. What next undertaken, and by whom? What result and conclusion? 521. What remarkable computation and letter? Result of Dr. Galle's search? 522. Who else investigating the subject at the same time? His conclusions? What fact does this establish? Why not Adams the discoverer?

lish the fact, that the new planet was discovered by calculation, though the failure of Mr. Adams to publish his conclusions, cut off his right to the honor of the discovery.

523. Since the discovery of this planet, it has been ascertained that it was seen as far back as 1795, though supposed to be a fixed star, and catalogued as such; and that all the irregularities of Uranus, with which astronomers were so much perplexed, are perfectly accounted for by the influence of the new planet.

524. On the 12th of October, 1846, Mr. Lassell, of Starfield, near Liverpool, discovered a satellite attendant upon Leverrier, and also, as he supposes, one or more *rings* similar to those of Saturn; but though the secondary has often been seen by others since, and has been made the basis of elaborate calculations respecting the mass of the primary, no further discovery of the rings has been made by any other observer.

CHAPTER IX.

COMETS—THEIR NATURE, MOTIONS, ORBITS, &c.

525. Comets, whether viewed as ephemeral meteors, or as substantial bodies, forming a part of the solar system, are objects of no ordinary interest. When, with uninstructed gaze, we look upwards, to the clear sky of evening, and behold, among the multitudes of heavenly bodies, one, blazing with its long train of light, and rushing onward towards the center of our system, we insensibly shrink back as if in the presence of a supernatural being. But when, with the eye of astronomy, we follow it through its perihelion, and trace it far off, beyond the utmost verge of the solar system, till it is lost in the infinity of space, not to return for centuries, we are deeply impressed with a sense of that power which could create and set in motion such bodies.

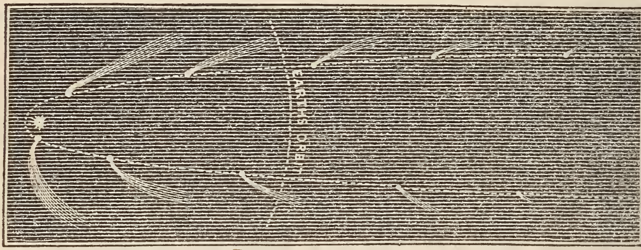
526. Comets are distinguished from the other heavenly bodies, by their appearance and motion. The appearance of the planets

523. Has Neptune ever been seen prior to 1846? What supposed to be? Does it account for the perturbation of Uranus? 524. Has Neptune a satellite? When, and by whom discovered? What said of *rings*? 525. Subject of this chapter? How comets regarded by the uninstructed? By the astronomer? 526. How distinguished

is globular, and their motion around the Sun is nearly in the same plane, and from west to east; but the comets have variety of forms, and their orbits are not confined to any particular part of the heavens; nor do they observe any one general direction.

The orbits of the planets approach nearly to circles, while those of the comets are very elongated ellipses. A wire hoop, for example, will represent the orbit of a planet. If two opposite sides of the same hoop be extended, so that it shall be long and narrow it will then represent the orbit of a comet. The Sun is always in one of the foci of the comet's orbit.

ORBIT OF A COMET.



Here it will be seen that the orbit is very eccentric, that the perihelion point is very near the Sun, and the aphelion point very remote.

There is, however, a practical difficulty of a peculiar nature which embarrasses the solution of the question as to the form of the cometary orbits. It so happens that the only part of the course of a comet which can ever be visible, is a portion throughout which the ellipse, the parabola, and hyperbola, so closely resemble each other, that no observations can be obtained with sufficient accuracy to enable us to distinguish them. In fact, the observed path of any comet, while visible, may belong either to an ellipse, parabola, or hyperbola.

527. That part which is usually *brighter*, or more *opaque*, than the other portions of the comet, is called the *nucleus*. This is surrounded by an *envelope*, which has a cloudy, or *hairy* appearance. These two parts constitute the body, and, in many instances, the whole of the comet. Most of them, however, are attended by a long train, called the *tail;* though some are without this appendage, and as seen by the naked eye, are not easily distinguished from the planets. Others again, have no apparent nucleus, and seem to be only globular masses of vapor.

Nothing is known with certainty of the composition of these bodies. The envelope appears to be nothing more than vapor, becoming more luminous and transparent when

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from other bodies? Form? Orbits? What practical difficulty mentioned? 527. What is the *nucleus* of a comet? The *envelope?* The *tail?* Have all comets these three parts? Do we understand of what they are composed? What evidence of their extreme tenuity?

approaching the Sun. As the comets pass between us and the fixed stars, their envelopes and tails are so thin, that stars of very small magnitude may be seen through them. Some comets, having no nucleus, are transparent throughout their whole extent.

528. The nucleus of a comet sometimes appears opaque, and it then resembles a planet. Astronomers, however, are not agreed upon this point. Some affirm that the nucleus is always transparent, and that comets are in fact nothing but a mass of vapor, more or less condensed at the center. By others it is maintained that the nucleus is sometimes solid and opaque. It seems probable, however, that there are three classes of comets, viz.; 1st. Those which have no nucleus, being transparent throughout their whole extent; 2d. Those which have a transparent nucleus; and, 3d. Those having a nucleus which is solid and opaque.

529. A comet, when at a distance from the Sun, viewed through a good telescope, has the appearance of a dense vapor surrounding the nucleus, and sometimes flowing far into the regions of space. As it approaches the Sun, its light becomes more brilliant, till it reaches its perihelion, when its light is more dazzling than that of any other celestial body, the Sun excepted. In this part of its orbit are seen to the best advantage the phenomena of this wonderful body, which has, from remote antiquity, been the specter of alarm and terror.

530. The luminous train of a comet usually *follows it*, as it approaches the Sun, and *goes before it*, when the comet recedes from the Sun; sometimes the tail is considerably curved towards the region to which the comet is tending, and in some instances, it has been observed to form a right angle with a line drawn from the Sun through the center of the comet. The tail of the comet of 1744, formed nearly a quarter of a circle; that of 1689 was curved like a Turkish sabre. (Map IX., Fig. 73.) Sometimes the same comet has several tails. That of 1744 had, at one time, no less than *six*, which appeared and disappeared in a few days. (See Map IX., Fig. 74.) The comet of 1823 had, for several days, two tails; one extending towards the Sun, and the other in the opposite direction.

531. Comets, in passing among and near the planets, are materially drawn aside from their courses, and in some cases have their orbits entirely changed. This is remarkably true in regard

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528. What difference of opinion respecting the nucleus of comets? What probable solution? 529. How do they appear when viewed through a telescope at a distance from the Sun? As it approaches him? Where seen to best advantage? 530. Usual direction of the trains of comets? Other positions? Comet of 1744? Of 1689? Of 1823? 531. Influence of attraction upon comets? Illustrations? Comet of 1770?

to Jupiter, which seems by some strange fatality to be constantly in their way, and to serve as a perpetual stumbling-block to them.

"The remarkable comet of 1770, which was found by Lexell to revolve in a moderate ellipse, in a period of about five years, actually *got entangled* among the satellites of Jupiter, and thrown out of its orbit by the attractions of that planet," and has not been heard of since.—*Herschel*, p. 310. By this extraordinary rencontre, the motions of Jupiter's satellites suffered not the least perceptible derangement; a sufficient proof of the aeriform nature of the comet's mass.

532. It is clear from observation, that comets contain very little *matter*. For they produce little or no effect on the motion of the planets when passing near those bodies; it is said that a comet, in 1454, eclipsed the Moon; so that it must have been very near the Earth; yet no sensible effect was observed to be produced by this cause, upon the motion of the Earth or the Moon.

The observations of philosophers upon comets, have as yet detected nothing of their nature. Tycho Brahe and Appian supposed their tails to be produced by the rays of the Sun transmitted through the nucleus, which they supposed to be transparent, and to operate as a lens. Kepler thought they were occasioned by the atmosphere of the comet, driven off by the impulse of the Sun's rays. This opinion, with some modification, was also maintained by Euler. Sir Isaac Newton conjectured that they were a thin vapor, rising from the heated nucleus, as smoke ascends from the Earth; while Dr. Hamilton supposed them to be streams of electricity.

"That the luminous part of a comet," says Sir John Herschel, "is something in the nature of a smoke, fog, or cloud, suspended in a transparent atmosphere, is evident from a fact which has been often noticed—viz., that the portion of the tail where it comes up to, and surrounds the head, is yet separated from it by an interval less luminous; as we often see one layer of clouds laid over another with a considerable clear space between them." And again: "It follows that these can only be regarded as great masses of thin vapor, susceptible of being penetrated through their whole substance by the sunbeams."

533. Comets have always been considered by the ignorant and superstitious, as the harbingers of war, pestilence, and famine. Nor has this opinion been, even to this day, confined to the unlearned. It was once universal. And when we examine the dimensions and appearances of some of these bodies, we cease to wonder that they produced universal alarm.

According to the testimony of the early writers, a comet which could be seen in daylight with the naked eye, made its appearance 43 years before the birth of our Saviour. This date was just after the death of Cæsar, and by the Romans, the comet was believed to be his metamorphosed soul, armed with fire and vengeance. This comet is again mentioned as appearing in 1106, and then resembling the Sun in brightness, being of a great size, and having an immense tail.* In the year 1402, a comet was seen, so brilliant as to be discerned at noon-day.

534. In 1456, a large comet made its appearance. It spread a wider terror than was ever known before. The belief was very general, among all classes, that the comet would destroy the Earth, and that the Day of Judgment was at hand!

532. What said of their physical natures? Opinion of Tycho Brahe? Of Kepler and Euler? Of Newton and Dr. Hamilton? Of Sir John Herschel? 533. How have comets usually been regarded by the ignorant? What remarkable comet mentioned? 534. What comet in 1456? Effect of its appearance? Has it appeared since? Its period?

The same comet appeared again in the years 1531, 1607, 1682, 1758 and 1835. It passed its perihelion in November, 1835, and will re-appear every 75½ years thereafter.

At the time of the appearance of this comet, the Turks extended their victorious arms across the Hellespont, and seemed destined to overrun all Europe. This added not a little to the general gloom. Under all these impressions, the people seemed totally regardless of the present, and anxious only for the future. The Romish Church held at this time unbounded sway over the lives, and fortunes, and consciences of men. To prepare the world for its expected doom, Pope Calixtus III. ordered the Ave Maria to be repeated three times a day, instead of two. He ordered the church bells to be rung at noon, which was the origin of that practice, so universal in Christian churches. To the Ave Maria, the prayer was added—"Lord! save us from the Devil, the Turk and the Comet;" and once, each day, these three obnoxious personages suffered a regular excommunication.

The Pope and clergy exhibiting such fear, it is not a matter of wonder that it became the ruling passion of the multitude. The churches and convents were crowded for confession of sins; and treasures uncounted were poured into the Apostolic chamber.

The comet, after suffering some months of daily cursing and excommunication, began to show signs of retreat, and soon disappeared from those eyes in which it found no favor. Joy and tranquillity soon returned to the faithful subjects of the Pope, but not so their money and lands. The people, however, became satisfied that their lives, and the safety of the world, had been cheaply purchased. The Pope, who had achieved so signal a victory over the monster of the sky, had checked the progress of the Turk, and kept, for the present, his Satanic majesty at a safe distance; while the Church of Rome, retaining her unbounded wealth, was enabled to continue that influence over her followers, which she retains, in part, to this day.

535. The comet of 1680 would have been still more alarming than that of 1456, had not science robbed it of its terrors, and history pointed to the signal failure of its predecessor. This comet was of the largest size, and had a tail whose enormous length was more than *ninety-six millions of miles.* (Map IX., Fig. 75.)

At its greatest distance, it is 13,000,000,000 of miles from the Sun; and at its nearest approach, only 574,000 miles from his center;* or about 130,000 miles from his surface. In that

* In Brewster's edition of Ferguson, this distance is stated as only 49,000 miles. This is evidently a mistake; for if the comet approached the Sun's center within 49,000 miles, it would penetrate 390,000 miles below the surface! Taking Ferguson's own elements for computing the perihelion distance, the result will be 494,460 miles. The mistake may be accounted for, by supposing that the cypher had been omitted in the copy, and the period pointed off one figure farther to the left. Yet, with this alteration, it would be still incorrect; because the Earth's mean distance from the Sun, which is the integer of this calculation, is assumed at 82,000,000 of miles. The ratio of the comet's perihelion distance from the Sun, to the Earth's mean distance, as given by M. Pingré, is as 0.00603 to 1. This multiplied into 95,273,869, gives 574,500 miles for the comet's perihelion distance from the Sun's *center;* from which, if we substract his semi-diameter, 443,840 miles, we shall have 130,660 miles, the distance of the comet from the surface of the Sun.

Again, if we divide the Earth's mean distance from the Sun, by the comet's perihelion distance, we shall find that the latter is only 1-166th part of the Earth's distance. Now the square of 166 is 27,556; and this expresses the number of times that the Sun appears *larger* to the comet, in the above situation, than it does to the Earth. Squire makes it 34,596 times larger.

According to Newton, the velocity is 880,000 miles per hour. More recent discoveries indicate a velocity of 1,240,108 miles per hour.

Incidents respecting the Turks and Church of Rome? 535. Comet of 1680? Length of its tail? Aphelion and perihelion distances? Rapidity of its motion when nearest the Sun? What error corrected? Appearance of the Sun from that point? Heat of the comet? Indicates what? Fanciful theory of Dr. Whiston, and remarks upon it?

part of its orbit which is nearest the Sun, it flies with the amazing swiftness of 1,000,000 miles in an hour, and the Sun, as seen from it, appears 27,000 times larger than it appears to us ; consequently, it is then exposed to a heat 27,000 times greater than the solar heat at the Earth. This intensity of heat exceeds, several thousand times, that of red-hot iron, and indeed all the degrees of heat that we are able to produce. A simple mass of vapor, exposed to a thousandth part of such a heat, would be at once dissipated in space—a pretty strong indication that, however volatile are the elements of which comets are composed, they are, nevertheless, capable of enduring an inconceivable intensity of both heat and cold.

This is the comet which, according to the reveries of Dr. Whiston and others, deluged the world in the time of Noah. Whiston was the friend and successor of Newton; but, anxious to know more than is revealed, he passed the bounds of sober philosophy, and presumed not only to fix the residence of the damned, but also the nature of their punishment. According to this theory, a comet was the awful prison-house in which, as it wheeled from the remotest regions of darkness and cold into the very vicinity of the Sun, hurrying its wretched tenants to the extremes of perishing cold and devouring fire, the Almighty was to dispense the severities of his justice. Such theories may be ingenious, but they have no basis of facts to rest upon. They more properly belong to the chimeras of Astrology, than to the science of Astronomy.

536. When we are told by philosophers of great caution and high reputation, that the fiery train of the comet, just alluded to, extended from the horizon to the zenith ; and that that of 1744 had, at one time, six tails, each 6,000,000 of miles long, long, and that another, which appeared soon after, had one 40,000,000 of miles long, and when we consider also the inconceivable velocity with which they speed their flight through the solar system, we may cease to wonder if, in the darker ages, they have been regarded as evil omens.

But these idle fantasies are not peculiar to any age or country. Even in our own times, the beautiful comet of 1811, the most splendid one of modern times, was generally considered among the superstitious, as the dread harbinger of the war which was declared in the following spring. It is well known that an indefinite apprehension of a more dreadful catastrophe lately pervaded both continents, in anticipation of Biela's comet of 1832.

537. The nucleus of the comet of 1811, according to observations made near Boston, was 2617 miles in diameter, corresponding nearly to the size of the Moon. The brilliancy with which it shone, was equal to one-tenth of that of the Moon. The envelope, or aeriform covering surrounding the nucleus, was 24,000 miles thick, about five hundred times as thick as the atmosphere which encircles the Earth ; making the diameter of comet, including its envelope, 50,617 miles. It had a very

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536. Why not strange that these comets were regarded as evil omens? Are such superstitions peculiar to any age or country? What illustrations? 537. Size of the comet of 1811? Its motion at its perihelion?

luminous tail, whose greatest length was *one hundred millions of miles.* Map IX., Fig. 76. This comet moved, in its perihelion, with an almost inconceivable velocity—fifteen hundred times greater than that of a ball bursting from the mouth of a cannon.

538. According to Regiomontanus, the comet of 1472 moved over an arc of 120° in one day. Brydone observed a comet at Palermo in 1770, which passed through 50° of a great circle in the heavens in 24 hours. Another comet, which appeared in 1759, passed over 41° in the same time. The conjecture of Dr. Halley, therefore, seems highly probable, that if a body of such a size, having any considerable density, and moving with such a velocity, were to strike our Earth, it would instantly reduce it to chaos, mingling its elements in ruin.

The transient effect of a body passing near the Earth, could scarcely amount to any great convulsion, says Dr. Brewster; but if the Earth were actually to receive a shock from one of these bodies, "having any considerable density," the consequences would indeed be awful. A new direction would be given to its rotary motion, and it would revolve around a new axis. The seas, forsaking their beds, would be hurried, by their centrifugal force, to the new equatorial regions; islands and continents, the abodes of men and animals, would be covered by the universal rush of the waters to the new equator, and every vestige of human industry and genius would be at once destroyed. But so far as we are as yet acquainted with these singular bodies, they are altogether too light and gasseous to produce any such results by collision.

539. The chances against such an event, however, are so very numerous, that there is no reason to dread its occurrence. The French government, not long since, called the attention of some of her ablest mathematicians and astronomers to the solution of this problem; that is, *to determine upon mathematical principles, how many chances of collision the Earth was exposed to.* After a mature examination, they reported—"We have found that, of 281,000,000 of chances, there is only *one* unfavorable—there exists but *one* which can produce a collision between the two bodies."

"Admitting, then," say they, "for a moment, that the comets which may strike the Earth with their nucleuses, would annihilate the whole human race; the danger of death to each individual, resulting from the appearance of an *unknown comet*, would be exactly equal to the risk he would run, if in an urn there was only *one single* white ball among a total number of 281,000,000 balls, and that his condemnation to death would be the inevitable consequence of the white ball being produced at the first drawing."

A little reflection, however, will show that all such fears are groundless. The same unerring hand that guides the ponderous planet in its way, directs also the majestic comet; and where infinite wisdom and almighty power direct, it is almost profane to talk of collision or accident.

540. We have before stated that comets, unlike the planets, observe no one direction in their orbits, but approach to, and recede from their great center of attraction, in every possible

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538. Velocity of the comet of 1472? Of 1770? Of 1759? Dr. Halley's conjecture? Dr. Brewster's? Could a comet produce any such effects? 539. Is such a collision probable? Why not? 540. What said of the orbits of comets and their various directions?

direction. Nothing can be more sublime, or better calculated to fill the mind with profound astonishment, than to contemplate the revolution of comets, while in that part of their orbits which comes within the sphere of the telescope. Some seem to come up from the immeasurable depths below the ecliptic, and, having doubled the heavens' mighty cape, again plunge downward with their fiery trains,

"On the long travel of a thousand years."

Others appear to come down from the zenith of the universe to double their perihelion about the Sun, and then reascend far above all human vision. Others are dashing through the solar system in all possible directions, and apparently without any undisturbed or undisturbing path prescribed by Him who guides and sustains them all.

541. Until within a few years, it was universally believed that the periods of their revolutions must necessarily be of prodigious length ; but within a few years, two comets have been discovered, whose revolutions are performed, comparatively, within our own neighborhood. To distinguish them from the more remote, they are denominated the *Comets of a short period.* The first was discovered in the constellation Aquarius, by two French astronomers, in the year 1786. The same comet was again observed by Miss Caroline Herschel, in the constellation Cygnus, in 1795, and again in 1805. In 1818, Professor Encke determined the dimensions of its orbit, and the period of its sidereal revolution ; for which reason it has been called "*Encke's Comet.*" Map IX., Fig. 77.

This comet performs its revolution around the Sun in about 3 years and 4 months, in an elliptical orbit which lies wholly within the orbit of Jupiter. Its *mean* distance from the Sun is 212,000,000 of miles; the eccentricity of its orbit is 179,000,000 of miles; consequently, is 358,000,000 of miles nearer the Sun in its perihelion, than it is in its aphelion. It was visible throughout the United States in 1825, when it presented a fine appearance. It was also observed at its next return in 1828; but its return to its perihelion on the 6th of May, 1832, was invisible in the United States, on account of its great southern declination. It has returned at regular periods since that time.

542. The second "comet of a short period," was observed in 1772 ; and was seen again in 1805. It was not until its reappearance in 1826, that astronomers were able to determine the elements of its orbit, and the exact period of its revolution. This was successfully accomplished by M. Biela of Josephstadt ; hence it is called *Biela's Comet.*

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541. What opinion respecting their periods? What distinction in comets founded on the lengths of their periods? History of "*Encke's Comet?*" Its period, orbit, mean distance, eccentricity of its orbit? 542. History of "*Biela's Comet?*" Its diameter?

According to observations made upon it in 1805, by the celebrated Dr. Olbers, its diameter, including its envelope, is 42,280 miles. It is a curious fact, that the path of Biela's Comet passes very near to that of the Earth; so near, that at the moment the center of the comet is at the point nearest to the Earth's path, the matter of the comet extends beyond that path, and includes a portion within it. Thus, if the Earth were at that point of its orbit which is nearest to the path of the comet, at the same moment that the comet should be at that point of its orbit which is nearest to the path of the Earth, the Earth would be enveloped in the nebulous atmosphere of the comet.

With respect to the effect which might be produced upon our atmosphere by such a circumstance, it is impossible to offer anything but the most vague conjecture. Sir John Herschel was able to distinguish stars as minute as the 16th or 17th magnitude *through the body of the comet!* Hence it seems reasonable to infer, that the nebulous matter of which it is composed, must be infinitely more attenuated than our atmosphere; so that for every particle of cometary matter which we should inhale, we should inspire millions of particles of atmospheric air.

543 This is one of the comets that was to come into collision with the Earth, and to blot it out from the Solar System. In returning to its perihelion, November 26th, 1832, it was computed that it would cross the Earth's orbit at a distance of only 18,500 miles. It is evident that if the Earth had been in that part of her orbit at the *same time* with the comet, our atmosphere would have mingled with the atmosphere of the comet, and the two bodies, perhaps, have come in contact. But the comet passed the Earth's orbit on the 29th of October, in the 8th degree of Sagittarius, and the Earth did not arrive at that point until the 30th of November, which was 32 days afterwards.

If we multiply the number of hours in 32 days, by 68,000 (the velocity of the Earth per hour), we shall find that the Earth was more than 52,000,000 miles behind the comet when it crossed her orbit. Its nearest approach to the Earth at any time, was about 51,000,000 of miles; its nearest approach to the Sun, was about 83,000,000 of miles. Its mean distance from the Sun, or half the longest axis of its orbit, is 337,000,000 of miles. Its eccentricity is 253,000,000 of miles; consequently, it is 507,000,000 of miles nearer the Sun in its perihelion than it is in its aphelion. The period of its sidereal revolution is 2460 days, or about 6¾ days.

544. Although the comets of Encke and Biela are objects of very great interest, yet their short periods, the limited space within which their motion is circumscribed, and consequently the very slight disturbance which they sustain from the attraction of the planets, render them of less interest to physical astronomy than those of longer periods. They do not, like them, rush from the invisible and inaccessible depths of space, and, after sweeping our system, depart to distances with the conception of which the imagination itself is confounded. They possess none of that grandeur which is connected with whatever appears to break through the fixed order of the universe.

What curious fact stated? What result if the Earth were to be enveloped in the comet? 543. What mischief formerly anticipated from Biela's comet? Its return in 1832? How near a collision in *distance* and in *time?* Its nearest approach to the Earth? To the Sun? Its mean distance from him? Its eccentricity and period? 544. Why are the comets of short periods less interesting than others? For what comet is it reserved to afford grounds for the proudest triumphs of mathematical science?

It is reserved for the comet of Halley alone to afford the proudest triumphs to those powers of calculation by which we are enabled to follow it in the depths of space, 2,000,000,000 of miles beyond the extreme verge of the solar system; and, notwithstanding the disturbances which render each succeeding period of its return different from the last, to foretell that return with precision. To be able to predict the very day and circumstances of the return of such a bodiless and eccentric wanderer, after the lapse of so many years, evinces a perfection of the astronomical *calculus* that may justly challenge our admiration.

545. "The re-appearance of Biela's comet," says Herschel, "whose return in 1832 was made the subject of elaborate calculations by mathematicians of the first eminence, did not disappoint the expectations of astronomers. It is hardly possible to imagine anything more striking than the appearance, after the lapse of nearly seven years, of such an all but imperceptible cloud or wisp of vapor, *true, however, to its predicted sime and place*, and obeying laws like those which regulate the planets."

Herschel, whose Observatory was at *Slough*, England, observed the daily progress of this comet from the 24th of September, until its disappearance, compared its *actual* position from day to day, with its *calculated* position, and found them to agree within four or five minutes of time in right ascension, and within a *few seconds* of declination. Its position, then, as represented on a planisphere which the author prepared for his pupils, and afterwards published, was true to within a less space than one-third of its projected diameter. Like some others that have been observed, this comet has no luminous train by which it can be easily recognized by the naked eye, except when it is very near the Sun. This is the reason why it was not more generally observed at its late return.

Although this comet is usually denominated "Biela's comet," yet it seems that M. Gambart, director of the Observatory at Marseilles, is equally entitled to the honor of identifying it with the comet of 1772, and of 1805. He discovered it only 10 days after Biela, and immediately set about calculating its elements from his own observations, which are thought to equal, if they do not surpass, in point of accuracy, those of every other astronomer.

546. Up to the beginning of the 17th century, no correct notions had been entertained in respect to the paths of comets. Kepler's first conjecture was that they moved in straight lines; but as that did not agree with observation, he next concluded that they were parabolic curves, having the Sun near the vertex, and running indefinitely into the regions of space at both extremities. There was nothing in the observations of the earlier astronomers to fix their identity, or to lead him to suspect that any one of them had ever been seen before; much less that they formed a part of the solar system, revolving about the Sun in elliptical orbits that returned into themselves.

547. This grand discovery was reserved for one of the most industrious and sagacious astronomers that ever lived—this was Dr. Halley, the cotemporary and friend of Newton. When the comet of 1682 made its appearance, he set himself about observing it with great care, and found there was a wonderful resem-

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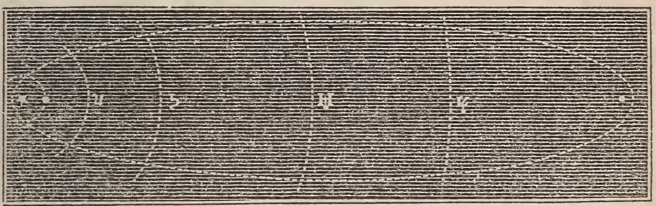
545. Remarks on the re-appearance of Biela's comet? What remarkable calculation referred to? Form of this comet? Is it really Biela's comet? 546. Former knowledge of the orbits of comets? 547. What grand discovery, and by whom? Process

blance between it and three other comets that he found recorded, the comets of 1456, of 1531, and 1607. The times of their appearance had been nearly at equal and regular intervals ; their perihelion distances were nearly the same ; and he finally proved them to be one and the same comet, performing its circuit around the Sun in a period varying a little from 76 years. It is, therefore, called *Halley's* comet. (Map IX., Fig. 78.)

The orbit of Halley's comet extends outward about 120,000,000 of miles beyond the orbit of Neptune, as represented in the following cut :

ORBIT OF HALLEY'S COMET.



This is the same comet that filled the eastern world with so much consternation in 1456, as stated on page 253, and became an object of such abhorrence to the Church of Rome.

The periodic times of the three comets just described. are as follow :

Encke's, 1212 days.
Biela's, 2461 days.
Halley's, 28,000 days.

Halley's comet, true to its predicted time and place, is now (Oct. 1835) visible in the evening sky. But we behold none of those phenomena which threw our ancestors of the middle ages into agonies of superstitious terror. We see not the *cometa horrendæ magnitudinis*, as it appeared in 1305, nor that tail of enormous length which, in 1456, extended over two-thirds of the interval between the horizon and the zenith, nor even a star as brilliant as was the same comet in 1682, with its tail of 30°.

Its mean distance from the Sun is 1,713,700,000 miles; the eccentricity of its orbit is 1,658,000,000 miles; consequently it is 3,316,000,000 miles farther from the Sun in its aphelion than it is in its perihelion. In the latter case its distance from the sun is only 55,700,000 miles; but in the former it is 3,371,700,000 miles. Therefore, though its aphelion distance be great, its mean distance is less than that of Uranus; and great as is the aphelion distance, it is but a very small fraction less than *one-five thousandth* part of that distance from the Sun, beyond which the very nearest of the fixed stars must be situated; and, as the determination of their distance is negative and not positive, the nearest of them may be at twice or ten times that distance.

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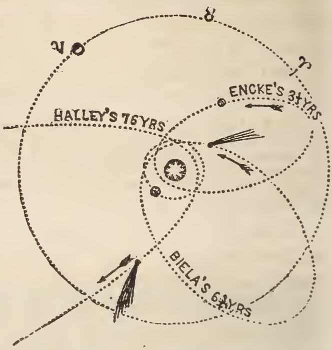
of the discovery? Aphelion distance of Halley's comet? What former visit to our system referred to? Periods of the three comets just described? Appearance of Halley's comet in 1835? Its mean distance from the Sun? How compare with that of Uranus? How does his greatest distance compare with that of the Fixed Stars?

OBBITS OF SEVERAL COMETS.



548. The orbit of Encke's comet is wholly within the orbit of Jupiter, while that of Biela's extends but a short distance beyond it. The aphelion distance of Halley's comet is 3,400,000,000 of miles, or 550,000,000 of miles beyond the orbit of Neptune. And even this is, in reality, a comet of short period compared with many that belong to our system.

549. The comet of 1819 was remarkable for its straight wedge-shaped appearance—not altogether unlike a shuttle-cock. It exhibited none of that curvature in its form which is an almost universal characteristic of cometary bodies. Map IX., Fig. 79.

550. The comet of 1843 was one of the most magnificent of modern times (See Map IX., Fig. 80). It was more than 60° in length. In the Southern Hemisphere it was so brilliant as to throw a very strong light upon the Earth. As its distance from the Sun varied, its color varied, from pale orange to "rose red," and then to white. "It passed its perihelion on the 27th of February, at which time it almost grazed the surface of the Sun, approaching nearer to that luminary than any comet hitherto observed. Its motions at this time were astonishingly swift, and its brilliancy such as to induce the belief that it was at a white heat through its whole extent. Its period is supposed to be 21$\frac{7}{8}$ years; consequently this must be its eighth return since 1668; and it will visit our sphere again in 1865."

At the time of the appearance of this comet, Rev. Mr. Miller and others were earnestly warning the people of the United States, that the world was to be burned up on the 23d of April following; and the appearance of the comet was regarded by many as an indication that the end of all things was at hand.

551. The number of comets which have been observed since the Christian era, amounts to 700. Scarcely a year has passed without the observation of one or two. And since multitudes of them must escape observation, by reason of their traversing that part of the heavens which is above the horizon in the day

548. Where are the orbits of Encke's and Biela's comets situated? What said of Halley's comet? 549. Comet of 1819? 550. That of 1843? Its length? Brilliancy? What variation in its color? Its perihelion passage? Heat? Its period? Next appearance? Incident of its last appearance? 551. Number of comets? Why so few seen?

time, their whole number is probably many thousands. Comets so circumstanced, can only become visible by the rare coincidence of a total eclipse of the Sun—a coincidence which happened, as related by Seneca, 60 years before Christ, when a large comet was actually observed very near the Sun.

But M. Arago reasons in the following manner, with respect to the number of comets:—The number of ascertained comets, which, at their least distances, pass within the orbit of Mercury, is thirty. Assuming that the comets are uniformly distributed throughout the solar system, there will be 117,649 times as many comets included within the orbit of Uranus, as there are within the orbit of Mercury. But as there are 30 within the orbit of Mercury, there must be 3,529,470 within the orbit of Uranus!

552. Of 97 comets whose elements have been calculated by astronomers, 24 passed between the Sun and the orbit of Mercury: 33 between the orbits of Mercury and Venus; 21 between the orbits of Venus and the Earth; 15 between the orbits of Ceres and Jupiter. 49 of these comets move from east to west, and 49 in the opposite direction. The total number of distinct comets, whose paths during the visible part of their course had been ascertained, up to the year 1855, was about one hundred and fifty.

553. What regions these bodies visit, when they pass beyond the limits of our view; upon what errands they come, when they again revisit the central parts of our system; what is the difference between their physical constitution and that of the Sun and planets; and what important ends they are destined to accomplish in the economy of the Universe, are inquiries which naturally arise in the mind, but which surpass the limited powers of the human understanding at present to determine.

554. Such is the celestial system with which our Earth was associated at its creation, distinct from the rest of the starry hosts. Whatever may be the comparative antiquity of our globe, and the myriads of radiant bodies which nightly gem the immense vault above us, it is most reasonable to conclude, that the Sun, Earth, and planets differ little in the date of their origin. This, fact, at least, seems to be philosophically certain, that all the bodies which compose our solar system must have been placed at one and the same time in that arrangement, and in those positions in which we now behold them; because all maintain their present stations, and motions, and distances, *by their mutual action on each other*. Neither could it be where it

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Phenomenon 60 years before Christ? M. Arago's reasoning and conclusion? 552. Perihelion distances of various comets? Directions in longitude? Number whose paths have been ascertained? 553. What inquiries awakened by the visits of cometary bodies? 554. Remarks respecting the date of the solar system? What supposed proof that the whole system was created at once?

is, nor move as it does, nor appear as we see it, unless they were all co-existent. The presence of each is essential to the system—the Sun to them, they to the Sun, and all to each other. This fact is a strong indication that their formation was simultaneous.

CHAPTER X.

OF THE FORCES BY WHICH THE PLANETS ARE RETAINED IN THEIR ORBITS.

555. HAVING described the real and apparent motions of the bodies which compose the solar system, it may be interesting next to show, that these motions, however varied or complex they may seem, all result from one simple principle, or law, namely, the

LAW OF UNIVERSAL GRAVITATION.

By *gravitation* is meant, that universal law of attraction, by which every particle of matter in the system has a tendency to every other particle. This attraction, or tendency of bodies towards each other, is in proportion to the quantity of matter they contain. The Earth, being immensely large in comparison with all other substances in its vicinity, destroys the effect of this attraction between smaller bodies, by bringing them all to itself.

It is said, that Sir Isaac Newton, when he was drawing to a close the demonstration of the great truth, that gravity is the cause which keeps the heavenly bodies in their orbits, was so much agitated with the magnitude and importance of the discovery he was about to make, that he was unable to proceed, and desired a friend to finish what the intensity of his feelings did not allow him to do.

556. The attraction of gravitation is reciprocal. All bodies not only attract other bodies, but are themselves attracted, and both according to their respective quantities of matter. The Sun, the largest body in our system, attracts the Earth and all the other planets, while they in turn attract the Sun. The

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555. Subject of this chapter? What is meant by gravitation? Upon what does the amount of this attraction depend? Influence of the Earth? Anecdote of Newton? 556. Is attraction reciprocal? What illustration cited? Ways in which attraction

Earth, also, attracts the Moon, and she in turn attracts the Earth. A ball, thrown upwards from the Earth, is brought again to its surface; the Earth's attraction not only counterbalancing that of the ball, but also producing a motion of the ball towards itself.

This disposition, or tendency towards the Earth, is manifested in whatever falls, whether it be a pebble from the hand, an apple from a tree, or an avalanche from a mountain. All terrestial bodies, not excepting the waters of the ocean, gravitate towards the center of the Earth, and it is by the same power that animals on all parts of the globe stand with their feet pointing to its center.

557. The power of terrestial gravitation is greatest at the Earth's surface, whence it decreases both upwards and downwards; but not both ways in the same proportion. It decreases upwards *as the square of the distance* from the Earth's center increases; so that at a distance from the center equal to twice the semi-diameter of the Earth, the gravitating force would be only one-fourth of what it is at the surface. But *below* the surface, it decreases in the *direct ratio* of the distance from the center; so that at a distance of half a semi-diameter from the center, the gravitating force is but half of what it is at the surface.

Weight and *Gravity*, in this case, are synonymous terms. We say a piece of lead weighs a pound, or 16 ounces; but if by any means it could be raised 4000 miles above the surface of the Earth, which is about the distance of the surface from the center, and consequently equal to two semi-diameters of the Earth above its center, it would weigh only one-fourth of a pound, or four ounces; and if the same weight could be raised to an elevation of 12,000 miles above the surface, or four semi-diameters above the center of the Earth, it would there weigh only one-sixteenth of a pound, or one ounce.

558. The same body, at the center of the Earth, being equally attracted in every direction, would be without weight; at 1000 miles from the center it would weigh one-fourth of a pound: at 2000 miles, one-half of a pound; at 3000 miles, three-fourths of a pound; and at 4000 miles, or at the surface, one pound.

It is a universal law of attraction, that *its power decreases as the square of the distance increases.* The converse of this is also true, viz.: *The power increases as the square of the distance decreases.* Giving to this law the form of a practical rule, it will stand thus:

The gravity of bodies above the surface of the Earth decreases in a duplicate ratio (or as the squares of their distances), in semi-diameters of the Earth, from the Earth's center. That is, when

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manifests itself? 557. Where is the power of terrestrial gravitation greatest? How diminished? In what ratio as we ascend above the Earth? As we descend toward its center? Are weight and gravity the same? 558. What would be the weight of a body at the Earth's center? At 100 miles from the center? At 2000 miles? At 4000? What universal law? What rule based upon this law? What illustrations given? What rule the gravity is *increasing, multiply* the weight by the square of the distance; but when the gravity is *decreasing, divide* the weight by the square of the distance.

Suppose a body weighs 40 pounds at 2000 miles above the Earth's surface, what would it weigh at the surface, estimating the Earth's semi-diameter at 4000 miles. From the center to the given height, is 1½ semi-diameters; the square of 1½, or 1.5 is 2.25, which, multiplied into the weight (40), gives 90 pounds, the answer.

Suppose a body which weighs 256 pounds upon the surface of the Earth, be raised to the distance of the Moon (240,000 miles), what would be its weight? Thus, 4000)240,000(60 semi-diameters, the square of which is 3600. As the gravity in this case is decreasing, *divide* the weight by the square of the distance, and it will give 3600)256(1-16th of a pound, or 1 ounce.

To find to what height a given weight must be raised to lose a certain portion of its weight.

RULE.—*Divide the weight at the surface by the required weight, and extract the square root of the quotient.* Ex. A boy weighs 100 pounds, how high must he be carried to weigh but 4 pounds? Thus, 100 divided by 4, gives 25, the square root of which is 5 semi-diameters, or 20,000 miles above the center.

559. Bodies of equal magnitude do not always contain equal quantities of matter; a ball of cork, of equal bulk with one of lead, contains less matter, because it is more porous. The Sun, though *fourteen hundred thousand* times larger than the Earth, being much less dense, contains a quantity of matter only 355,000 as great, and hence attracts the Earth with a force only 355,000 times greater than that with which the Earth attracts the Sun.

The quantity of matter in the Sun is 780 times greater than that of all the planets and satellites belonging to the Solar System; consequently, their whole united force of attraction is 780 times less upon the Sun, than that of the Sun upon them.

CENTER OF GRAVITY.

560. The *Center of Gravity* of a body, is that point in which its whole weight is concentrated, and upon which it would rest, if freely suspended. If two weights, one of ten pounds, the other of one pound, be connected together by a rod eleven feet long, nicely poised on a center, and then be thrown into a free rotary motion, the heaviest will move in a circle with a radius of one foot, and the lightest will describe a circle with a radius of ten feet; the center around which they move is their common center of gravity. (See the Figure.)

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to find what height a given weight must be raised to lose a certain portion of its weight? 559. Do bodies attract in proportion to their bulk? Why not? What illustrations? Quantity of matter in the Sun? 560. What is meant by the center of gravity? Illustration? How with the Sun and planets? How would it be if there was

Thus the Sun and planets move around in an imaginary point as a center, always preserving an equilibrium.

If there were but one body in the universe, provided it were of uniform density, the center of it would be the center of gravity towards which all the surrounding portions would uniformly tend, and they would thereby balance each other. Thus the center of gravity, and the body itself, would for ever remain at rest. It would neither move up nor down; there being no other body to draw it in any direction. In this case, the terms *up* and *down* would have no meaning, except as applied to the body itself, to express the direction of the surface from the center.

561. Were the Earth the only body revolving about the Sun, as the Sun's quantity of matter is 355,000 times as great as that of the Earth, the Sun would revolve in a circle equal only to the *three hundred and fifty-five thousandth* part of the Earth's distance from it; but as the planets in their several orbits vary their positions, the center of gravity is not always at the same distance from the Sun.

The quantity of matter in the Sun so far exceeds that of all the planets together, that were they all on one side of him, he would never be more than his own diameter from the common center of gravity; the Sun is, therefore, justly considered as the center of the system.

562. The quantity of matter in the Earth being about 80 times as great as that of the Moon, their common center of gravity is 80 times nearer the former than the latter, which is about 3000 miles from the Earth's center. The secondary planets are governed by the same laws as their primaries, and both together move around a common center of gravity. Every system in the universe is supposed to revolve in like manner, around *one common center.*

ATTRACTIVE AND PROJECTILE FORCES.

563. All simple motion is naturally rectilinear; that is, all bodies put in motion would continue to go forward in straight lines, as long as they met with no resistance or diverting force. On the other hand, the Sun, from his immense size, would, by the power of attraction, draw all the planets to him, if his attractive force were not counterbalanced by the primitive impulse of the planetary bodies to move in straight lines.

564. The attractive power of a body drawing another body

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but one body in the universe? 561. Suppose the Earth was the only body revolving around the Sun? Is the center of gravity always at the same distance from the Sun? Why not? How would it be if all the planets were on one side of him? 562. What is the amount of matter in the Earth as compared with the Moon? How with the secondary planets? With other systems in the universe? 563. What is the character of all simple motion? What illustrations given? 564 What is the attractive power called?

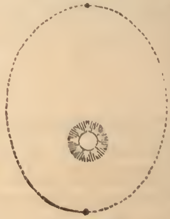
towards the center, is denominated *Centripetal force;* and the tendency of a revolving body to fly *from* the center in a tangent line, is called the *Projectile* or *Centrifugal force.* The joint action of these two central *forces* gives the planets a circular motion, and retains them in their orbits as they revolve, the primaries about the Sun, and the secondaries about their primaries.

565. The *degree* of the Sun's attractive power at each particular planet, whatever be its distance, is uniformly equal to the centrifugal force of the planet. The nearer any planet is to the Sun, the more strongly is it attracted by him ; the farther any planet is from the Sun, the less is it attracted by him ; therefore, those planets which are the nearer to the Sun, must move the faster in their orbits, in order thereby to acquire centrifugal forces equal to the power of the Sun's attraction ; and those which are the farther from the Sun, must move the slower, in order that they may not have too great a degree of centrifugal force, for the weaker attraction of the Sun at those distances.

LAWS OF PLANETARY MOTION.

566. Three very important laws, governing the movements of the planets, were discovered by *Kepler*, a German astronomer, in 1609. In honor of their discoverer, they are called *Kepler's Laws.* *Kepler* was a disciple of *Tycho Brahe*, a noted astronomer of Denmark, and was equally celebrated with his renowned tutor. His residence and observatory were at Wirtemburgh, in Germany.

APHELION.



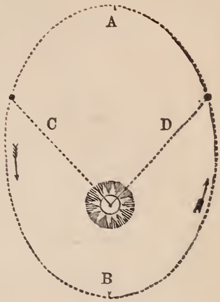
PERIHELION.

The *first* of these laws is, that *the orbits of all the planets are elliptical, having the Sun in the common focus.*

The point in a planet's orbit nearest the Sun is called the *perihelion* point, and the point most remote the *aphelion* point. *Perihelion* is from *peri*, about or near, and *helios*, the Sun; and *aphelion*, from *apo*, from, and *helios*, the Sun.

From this first law of Kepler, it results that the planets move with different velocities, in different parts of their orbits. From the aphelion to the perihelion points, the centripetal force *combines with* the centrifugal to accelerate the planet's motion; while from perihelion to aphelion points, the centripetal acts *against* the centrifugal force, and *retards* it.

The tendency to depart from the center? What does the joint action of these two forces produce? 565. What relation between the Sun's attraction and the centrifugal force of the planets? What effect has the *distance* of a planet from the Sun, upon his attractive force? How is this increased tendency counterbalanced? 566. What important laws—when and by whom discovered? State the first? What are the *aphelion* and *perihelion* points? Derivation? What results from this first law?

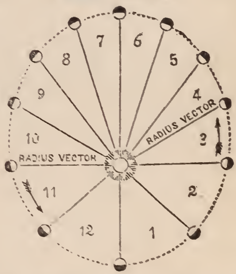


From A to B in the diagram, the centrifugal force, represented by the line C, acts *with* the tendency to revolve, and the planet's motion is *accelerated;* but from B to A the same force, shown by the line D, acts *against* the tendency to advance, and the planet is *retarded.* Hence it comes to aphelion with its least velocity, and to perihelion with its greatest.

In the statement of velocities on page 45, the *mean* or *average* velocity is given.

567. The *second* law is, that the *radius vector of a planet describes equal areas in equal times.* The *radius* is an imaginary line joining the center of the Sun and the center of the planet, in any part of its orbit. *Vector* is from *veho,* to carry; hence the *radius vector* is a radius carried round. By the statement that *it describes equal areas in equal times,* is meant that it sweeps over the same surface in an hour, when a planet is near the Sun, and moves swiftly, as, when furthest from the Sun, it moves most slowly.

RADIUS VECTOR.



The nearer a planet is to the Sun, the more rapid its motion. It follows, therefore, that if the orbit of a planet is an ellipse, with the Sun in one of the foci, its rate of motion will be unequal in different parts of its orbit—swiftest at perihelion, and slowest at aphelion. From perihelion to aphelion the centripetal more directly counteracts the centrifugal force, and the planet is *retarded.* On the other hand, from the aphelion to the perihelion point, the centripetal and centrifugal forces are united, or act in a similar direction. They consequently hasten the planet onward, and its rate of motion is constantly *accelerated.* Now suppose, when the planet is at a certain point near its perihelion, we draw a line from its center to the center of the Sun. This line is the *radius vector.* At the end of one day, for instance, after the planet has advanced considerably in its orbit, we draw another line in the same manner to the Sun's center, and estimate the area between the two lines. At another time, when the planet is near its aphelion, we note the space over which the radius vector travels in one day, and estimate its area. On comparison, it will be found, that notwithstanding the unequal *velocity* of the planet, and consequently of the radius vector, at the two ends of the ellipse, the *area* over which the radius vector has traveled is the same in both cases. The same principle obtains in every part of the planetary orbits, whatever may be their ellipticity or the mean distance of the planet from the Sun; hence the rule that *the radius vector describes equal areas in equal times.* In the preceding cut, the twelve triangles, numbered 1, 2, 3, &c., over each of which the radius vector sweeps in equal times, are equal.

568. The *third* law of Kepler is, that *the squares of the periodic times of any two planets are proportioned to the cubes of their mean distances from the Sun.*

Take, for example, the Earth and Mars, whose periods are 365·2564 and 686·9796 days, and whose distances from the Sun are in the proportion of 1 to 1·52369, and it will be found that $(365.2564)^2 : (686.9796)^2 :: (1)^3 : (1.52369)^3$.

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567. State the *second* law of Kepler? Explain it? 568. The *third* law? What illustration?

According to these laws, which are known to prevail throughout the solar system, many of the facts of astronomy are deduced from other facts previously ascertained. They are, therefore, of great importance, and should be studied till they are, at least, thoroughly understood, if not committed to memory.

569. From the foregoing principles, it follows, that the force of gravity, and the centrifugal force, are mutual *opposing powers* —each continually acting against the other. Thus, the weight of bodies on the Earth's equator, is *diminished* by the centrifugal force of her diurnal rotation, in the proportion of one pound for every 290 pounds: that is, had the Earth no motion on her axis, all bodies on the equator would weigh one *two hundred and eighty-ninth part* more than they now do.

On the contrary, if her diurnal motion were accelerated, the centrifugal force would be proportionally increased, and the weight of bodies at the equator would be in the same ratio diminished. Should the Earth revolve upon its axis with a velocity which would make the day but 84 minutes long, instead of 24 hours, the centrifugal force would counterbalance that of gravity, and all bodies at the equator would then be absolutely destitute of weight; and if the centrifugal force were further augmented (the Earth revolving in less than 84 minutes), gravitation would be completely overpowered, and all fluids and loose substances near the equator would fly off from the surface.

570. The weight of bodies, either upon the Earth, or on any other planet having a motion around its axis, depends jointly upon the mass of the planet, and its diurnal velocity. A body weighing one pound upon the equator of the Earth, would weigh, if removed to the equator of the Sun, 27.9 lbs.; of Mercury, 1.03 lbs.; of Venus, 0.98 lbs.; of the Moon, 1-6th of a-lb.; of Mars, ½ lb.; of Jupiter, 2.716 lbs.; of Saturn, 1.01 lbs.

CHAPTER XI.

PROPER MOTION OF THE SUN IN SPACE.

571. Though we are accustomed to speak of the Sun as the *fixed* center of the Solar System, the idea of his fixedness is correct only so far as his relation to the bodies revolving around him are concerned. As the planets accompanied by their satellites revolve around the Sun, so he is found to be moving with all his retinue of worlds, in a *vast orbit*, around some distant and unknown center.

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569. What results from these principles, as respects the weight of bodies on the Earth's surface? How increased or diminished? What illustrations given? 570. Upon what, then, does the weight of bodies upon the planets depend? What illustrations? 571. Is the Sun a fixed body? What motion in space? Who first advanced this idea?

This opinion was first advanced, we think, by Sir William Herschel; but the honor of actually determining this interesting fact, belongs to Struve, who ascertained not only the *direction* of the Sun and Solar System, but also their *velocity*. The point of tendency is towards the constellation Hercules, Right Ascension 259°, Declination 35°. The *velocity* of the Sun, &c., in space, is estimated at about 20,000 miles per hour, or nearly 8 miles per second;

572. With this wonderful fact in view, we may no longer consider the Sun as fixed and stationary, but rather as a vast and luminous *planet*, sustaining the same relation to some central orb, that the primary planets sustain to him, or that the secondaries sustain to their primaries. Nor is it necessary that the stupendous mechanism of nature should be restricted even to these sublime proportions. The Sun's central body may also have its orbit, and its center of attraction and motion, and so on, till, as Dr. Dick observes, we come to the great center of all—to the THRONE OF GOD.

THE CENTRAL SUN.

573. In 1847, an article appeared in several European journals, announcing the probable discovery by Professor Mädler, of Dorpat, of the Sun's *central orb*; the *inclination of his orbit to the plane of the ecliptic*; and his *periodic time!*

By an extensive and laborious comparison of the quantities and directions of the proper motions of the stars in various parts of the heavens, combined with indications afforded by the parallaxes hitherto determined, and with the theory of universal gravitation, Professor Mädler arrived at the conclusion that the Pleiades form the central group of our whole astral or sidereal system, including the Milky Way and all the brighter stars, but exclusive of the more distant nebulæ, and of the stars of which those nebulæ may be composed. And within this central group itself he has been led to fix on the star Alcyone, as occupying exactly or nearly the position of the center of gravity, and as entitled to be called the central Sun.

Assuming Bessel's parallax of the star 61 Cygni, long since remarkable for its larger proper motion, to be correctly determined, Mädler proceeds to form a first approximate estimate of the distance of this central body from the planetary or solar system; and arrives at the provisional conclusion, that Alcyone is about 34,000,000 times as far removed from us, or from our own Sun, as the latter luminary is from us. It would, therefore, according to this estimation, be at least a million times as distant as the new planet, of which the theoretical or deductive discovery has been so great and beautiful a triumph of modern astronomy, and so striking a confirmation of the law of Newton. The same approximate determination of distance conducts to the result, that the light of the central sun occupies more than five centuries in travelling thence to us.

Direction and velocity of the Sun and Solar System? 572. How, then, should we regard the Sun? What further speculation? Dr. Dick's observation? 573. What great discovery in 1847, and by whom? By what process? What conclusion first reached? What star afterward designated? Further description of the progress of the discovery? What conclusion respecting the passage of light from the central Sun to us?

574. The enormous orbit which our own Sun, with the Earth, and the other planets, is thus inferred to be describing about that distant center—not, indeed, under its influence alone, but by the combined attractions of all the stars which are nearer to it than we are, and which are estimated to amount to more than 117,000,000 of masses, each equal to the total mass of our own Solar System—is supposed to require upwards of *eighteen millions of years* for its complete description, at the rate of about eight geographical miles in every second of time. At this rate, the arc of its orbit, over which the Sun has traveled since the creation of the world, amounts to only about $\frac{1}{3000}$th part of his orbit, or about 7 minutes—an arc so small, compared with the whole, as to be hardly distinguishable from a straight line.

The plane of this vast orbit of the Sun is judged to have an inclination of about 84 degrees to the ecliptic, or to the plane of the annual orbit of the Earth; and the longitude of the ascending node of the former orbit on the latter is concluded to be nearly 232 degrees.

CHAPTER XII.

PRECESSION OF THE EQUINOXES—OBLIQUITY OF THE ECLIPTIC.

575. Of all the motions which are going forward in the Solar System, there is none, which it is important to notice, more difficult to comprehend, or to explain, than what is called the PRECESSION OF THE EQUINOXES.

The equinoxes, as we have learned, are the two opposite

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574. Supposed period of the Sun's revolution? What portion of his orbit gone over since the creation of our race? Situation of his orbit with respect to the ecliptic? Longitude of ascending node? 575. Subject of this chapter? What are the equinoxes?

points in the Earth's orbit, where it crosses the celestial equator. The first is in Aries; the other, in Libra. By the *precession* of the equinoxes is meant, that the intersection of the equator with the ecliptic is not always in the same point :—in other words, that the Sun, in its apparent annual course, does not cross the equinoctial, Spring and Autumn, exactly in the same points, but every year a little *behind* those of the preceding year.

576. This annual falling back of the equinoctial points, is called by astronomers, with reference to the motion of the heavens, the *Precession of the Equinoxes;* but it would better accord with fact as well as the apprehension of the learner, to call it, as it is, the *Recession* of the Equinoxes ; for the equinoctial points do actually *recede* upon the ecliptic, at the rate of about $50\frac{1}{4}''$ of a degree every year. It is the name only, and not the position, of the equinoxes which remains permanent. *Wherever* the Sun crosses the equinoctial in the *spring*, *there* is the vernal equinox ; and *wherever* he crosses it in the *autumn*, *there* is the autumnal equinox ; and these points are constantly moving to the west.

PRECESSION OF THE EQUINOXES.

To render this subject familiar, we will suppose two carriage roads, extending quite around the Earth; one, representing the equator, running due east and west; and the other representing the ecliptic, running nearly in the same direction as the former, yet so as to cross it with a small angle (say of 23½°), both at the point where we now stand, for instance, and in the nadir, exactly opposite; let there also be another road, to represent the prime meridian, running north and south, and crossing the first at right angles, in the common point of intersection, as in the annexed figure.

Let a carriage now start from this point of intersection, not in the road leading directly east, but along that of the ecliptic, which leaves the former a little to the north, and let a person be placed to watch when the carriage comes around again, after having made the circuit of the Earth, and see whether the carriage will cross the equinoctial road again precisely in the *same track* as when it left the goal. Though the person stood exactly in the former track, he need not fear being run over, for the carriage will cross the road 100 rods west of him, that is 100 rods west of the meridian on which he stood. It is to be observed, that 100 rods on the equator is equal to 50¼ seconds of a degree.

If the carriage still continue to go around the Earth, it will, on completing its second

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What meant by their precession? 576. With reference to what is it a *precession?* Is it really a *precession* of the equinoxes? Where are the equinoxes spring and fall? Can you illustrate by the two carriage roads, &c.? By the other diagram? Does the Sun circuit, cross the equinoctial path 200 rods west of the meridian whence it first set out; on the third circuit, 300 rods west; on the fourth circuit, 400 rods, and so on, continually. After 71⅔ circuits, the point of intersection would be one degree west of its place at the commencement of the route. At this rate it would be easy to determine how many complete circuits the carriage must perform before this continual falling back of the intersecting point would have retreated over every degree of the orbit, until it reached again the point from whence it first departed. The application of this illustration will be manifest when we consider, further, that this interesting phenomenon may be explained in another way by the adjoining diagram. Let the point A represent the vernal equinox, reached, for instance, at 12 o'clock on the 20th of March. The next year the Sun will be in the equinoctial 22 minutes 33 seconds earlier, at which time the Earth will be 50¼″ on the ecliptic, back of the point at which the Sun was in the equinoctial the year before. The next year the same will occur again; and thus the equinoctial point will recede westward little by little, as shown by the small lines from A to B, and from C to D. It is in reference to the stars going forward, or seeming to *precede* the equinoxes, that the phenomenon is called the Precession of the Equinoxes. But in reference to the motion of the equinoxes themselves, it is rather a *recession*.

RECESSION OF THE EQUINOXES.

577 The Sun revolves from one equinox to the same equinox again, in 365d. 5h. 48′ 47″.81. This constitutes the natural, or *tropical year*, because, in this period, one revolution of the seasons is exactly completed. But it is, meanwhile, to be borne in mind, that the equinox itself, during this period, has not kept its position among the stars, but has deserted its place, and *fallen back* a little way to meet the Sun; whereby the Sun has arrived at the equinox *before* he has arrived at the same position among the stars from which he departed the year before; and, consequently, must perform as *much more* than barely a *tropical* revolution, to reach that point again.

To pass over this interval, which *completes the Sun's sidereal revolution*, takes (20′ 22″.94) about 22 minutes and 23 seconds longer. By adding 22 minutes and 23 seconds to the time of a tropical revolution, we obtain 365d. 6h. 9m. 10¾s. for the length of a *sidereal revolution;* or the time in which the Sun revolves from one fixed star to the same star again.

Though we speak of the revolution of the Sun, we mean simply his *apparent* revolution eastward around the heavens, caused wholly by the actual revolution of the Earth in her

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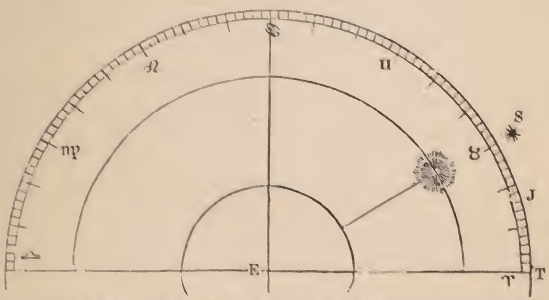
actually revolve? Why, then, speak of his revolution? 577. What is the length of a tropical year? How different from a sidereal year? Difference of *time?* Length of a sidereal year?

orbit, as a distant object would appear to sweep around the horizon if we were walking or sailing around it. This may be illustrated by the cut, page 288, where the passage of the Earth from A to B would cause the Sun to appear to move from C to D; and so on around the whole circle of the Zodiac.

578. As the Sun describes the whole ecliptic, or 360°, in a tropical year, he moves over 59′ 8⅓″ of a degree every day, at a mean rate, which is equal to 50¼″ of a degree in 20 minutes and 23 seconds of time; consequently he will arrive at the same equinox or solstice when he is 50¼″ of a degree *short of the same star* or fixed point in the heavens, from which he set out the year before. So that, with respect to the fixed stars, the Sun and equinoctial points fall back, as it were, 1° in 71⅔ years. This will make the stars *appear to have gone forward* 1°, with respect to the *signs* in the ecliptic, in that time; for it must be observed, that *the same signs always keep in the same points of the ecliptic, without regard to the place of the constellations.* Hence it becomes necessary to have new plates engraved for celestial globes and maps, at least once in 50 years, in order to exhibit truly the altered position of the stars. At the present rate of motion, the *recession* of the equinoxes, as it should be called, or the *precession* of the stars, amounts to 30°, or one whole sign, in 2140 years.

PRECESSION OF THE STARS.



To explain this by a figure: Suppose the Sun to have been in conjunction with a fixed star at S. in the first degree of Taurus (the second sign of the ecliptic), 340 years before the birth of our Saviour, or about the seventeenth year of Alexander the Great; then having made 2140 revolutions through the ecliptic, he would be found again at the end of so many *sidereal years* at S; but at the end of so many *Julian years*, he would be found at J, and at the end of so many *tropical years*, which would bring it down to the beginning of the present century, he would be found at T, in the first degree of Aries, which

578. Daily progress of the Sun? What is the amount of the annual recession of the equinoxes? What effect will this have upon the apparent positions of the stars? Hence what becomes necessary? How long does it require for the equinoxes to recede a whole sign? Do you understand the diagram, and the reference to the sidereal, Julian, and Tropical years? Explain the difference in these three kinds of years.

has receded from S to T in that time by the precession of the equinoctial points Aries and Libra. The arc S T would be equal to the amount of the precession (*for precession* we must still call it) of the equinox in 2140 years, at the rate of 50".23572 of a degree, or 20 minutes and 23 seconds of time annually, as above stated.

579. From the constant retrogradation of the equinoctial points, and with them of all the signs of the ecliptic, it follows that *the longitude of the stars must continually increase.* The same cause affects also their *right ascension and declination.* Hence, those stars which, in the infancy of astronomy, were in the sign *Aries*, we now find in *Taurus ;* and those which were in *Taurus*, we now find in *Gemini*, and so on. Hence likewise it is, that the star which rose or set at any particular time of the year, in the time of Hesiod, Eudoxus, Virgil, Pliny, and others, by no means answers at this time to their descriptions.

Hesiod, in his *Opera et Dies*, lib. ii. verse 185, says:

"When from the solstice sixty wintry days
Their turns have finished, mark, with glitt'ring rays,
From Ocean's sacred flood, Arcturus rise,
Then first to gild the dusky evening skies."

But Arcturus *now* rises acronically in latitude 37° 45′ N. the latitude of Hesiod, and nearly that of Richmond, in Virginia, about 100 days after the winter solstice. Supposing Hesiod to be correct, there is a difference of 40 days arising from the precession of the equinoxes since the days of Hesiod. Now, as there is no record extant of the exact period of the world when this poet flourished, let us see to what result astronomy will lead us.

As the Sun moves through about 39° of the ecliptic in 40 days, the winter solstice, in the time of Hesiod, was in the 9th degree of Aquarius. Now, estimating the precession of the equinoxes at 50¼" in a year, we shall have 50¼" : 1 year : : 39 : 2814 years since the time of Hesiod: if we subtract from this our present era, 1855, it will give 958 years before Christ. Lempriere, in his Classical Dictionary, says Hesiod lived 907 years before Christ. See a similar calculation for the time of Thales, page 39.

580. The retrograde movement of the equinoxes, and the annual extent of it, were determined by comparing the longitude of the same stars, at different intervals of time. The most careful and unwearied attention was requisite in order to determine the cause and extent of this motion—a motion so very slow as scarcely to be perceived in an age, and occupying not less than 25,000 years in a single revolution. It has not yet completed *one quarter of its first circuit* in the heavens since the creation of Mars.

581. This observation has not only determined the absolute motion of the equinoctial points, but measured its limit ; it has also shown that this motion, like the causes which produce it, is not uniform in itself ; but that it is constantly accelerated by a

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579. What effect has the recession of the equinoxes upon the longitude of the stars, and their right ascension and declination? Hence what results? What interesting calculation in reference to Hesiod? 580. How were this recession and its extent determined? What necessary? Time of complete revolution? Amount since creation? 581. Is this retrogression uniform? Amount of acceleration? What illustration given?

slow arithmetical increase of 1″ of a degree in 4100 years. A quantity which, though totally inappreciable for short periods of time, becomes sensible after a lapse of ages.

For example: The retrogradation of the equinoctial points is now greater by nearly ½″ than it was in the time of *Hipparchus*, the first who observed this motion; consequently, the mean tropical year is *shorter* now by about 12 seconds than it was then. For, since the retrogradation of the equinoxes is now every year greater than it was then, the Sun has, each year, a space of nearly ½″ *less to pass through* in the ecliptic, in order to reach the plane of the equator. Now the Sun is 12 seconds of *time* in passing over ½″ of *space*.

582. At present, the equinoctial points move *backwards*, or *from east to west* along the path of the ecliptic at the rate of 1° in 71⅔ years, or one whole sign in 2140 years. Continuing at this rate, they will fall back through the whole of the 12 signs of the ecliptic in 25,680 years, and thus return to the *same position among the stars*, as in the beginning.

But in determining the period of a complete revolution of the equinoctial points, it must be borne in mind that the motion itself is *continually increasing;* so that the last quarter of the revolution is accomplished several hundred years sooner than the first quarter. Making due allowance for this accelerated progress, the revolution of the equinoxes is completed in 25,000 years; or, more exactly, in 24,992 years.

Were the motion of the equinoctial points uniform; that is, did they pass through equal portions of the ecliptic in equal times, they would accomplish their first quarter, or pass through the *first three signs* of the ecliptic, in 6250 years. But they are 6575 years in passing through the first quarter; about 218 years *less* in passing through the second quarter; 218 less in passing through the third, and so on.

583. The immediate consequence of the precession of the equinoxes, as we have already observed, is a *continually progressive increase of longitude* in all the heavenly bodies. For the vernal equinox being the initial point of longitude, as well as of right ascension, a retreat of this point on the ecliptic tells upon the longitude of all alike, whether at rest or in motion, and produces, so far as its amount extends, the *appearance* of a motion in longitude common to them all, *as if* the whole heavens had a slow rotation around the poles of the ecliptic in the long period above mentioned, similar to what they have in every twenty-four hours around the poles of the equinoctial. As the Sun *loses* one day in the year on the stars, by his *direct* motion in longitude; so the equinox *gains* one day on them in 25,000 years, by its *retrograde* motion.

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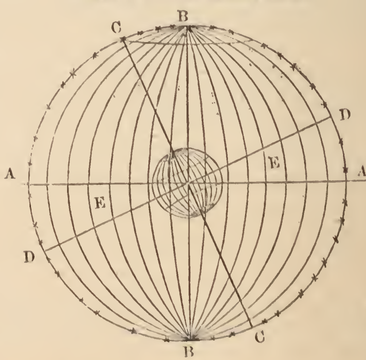
582. Present rate of motion? Exact period at this rate? Period making allowance for acceleration? Time of passing over the first quarter of the ecliptic? The second? Third? 583. What immediate consequences of the precession of the equinoxes? *Why* does it affect the longitude of the stars? What resemblance between the motion of the celestial sphere and that of the Earth? Between the Sun and equinoxes?

584. The cause of this motion was unknown, until Newton proved that it was a necessary consequence of the rotation of the Earth, combined with its elliptical figure, and the unequal attraction of the Sun and Moon on its polar and equatorial regions. There being more matter about the Earth's equator than at the poles, the former is more strongly attracted than the latter, which causes a slight gyratory or wabbling motion of the poles of the Earth around those of the ecliptic, like the pin of a top about its center of motion, when it spins a little obliquely to the base.

585. The precession of the equinoxes, thus explained, consists in a real motion of the pole of the heavens among the stars, in a small circle around the pole of the ecliptic as a center, keeping constantly at its present distance of nearly 23½° from it, in a direction from east to west, and with a progress so very slow, as to require 25,000 years to complete the circle. During this revolution, it is evident that the pole will point successively to every part of the small circle in the heavens which it thus describes. Now this cannot happen without producing corresponding changes in the apparent diurnal motion of the sphere, and in the aspect which the heavens must present at remote periods of time.

NUTATION OF THE EARTH'S AXIS.



Let the line A A in the figure represent the plane of the ecliptic; B B, the poles of the ecliptic; C C, the poles of the Earth; and D D, the equinoctial. E E is the obliquity of the ecliptic. The star C, at the top, represents the pole star, and the curve line passing to the right from it, may represent the circular orbit of the north pole of the heavens around the north pole of the ecliptic.

586. The effect of such a motion on the aspect of the heavens, is seen in the *apparent* approach of some stars and constellations to the celestial pole, and the recession of others. The bright star of the Lesser Bear, which we call the *pole star*, has not always been, nor will always continue to be, our polar star. At the time of the con-

584. What said of the *cause* of this recession? 585. Of what, then, does it consist? What said of the pole of the ecliptic, and the aspects of the heavens during this revolution? 585. How is the effect of this motion manifested? How with the Pole star?

struction of the earliest catalogue, this star was 12° from the pole; it is now only 1° 34′ from it, and it will approach to within half a degree of it; after which it will again recede, and slowly give place to others, which will succeed it in its proximity to the pole.

The *pole*, as above considered, is to be understood, merely, as the *vanishing point* of the Earth's axis; or that point in the concave sphere which is *always opposite* the terrestial pole, and which consequently must move as that moves.

587. The precession of the stars in respect to the equinoxes, is less apparent the greater their distance from the ecliptic; for whereas a star in the *zodiac* will appear to sweep the whole circumference of the heavens in an equinoctial year, a star situated within the *polar circle* will describe only a very small circle in that period, and by so much the less, as it approaches the pole. The north pole of the Earth being elevated 23° 27½′ towards the tropic of Cancer, the circumpolar stars will be successively at the least distance from it, when their longitude is 3 signs or 90°.

588. The position of the north polar star in 1855, was in the 17° of *Taurus;* when it arrives at the first degree of Cancer, which it will do in about 250 years, it will be at its nearest possible approach to the pole—namely, 29′ 55″. About 2900 years before the commencement of the Christian era, *Alpha Draconis,* the third star of the Dragon's tail, was in the first degree of Cancer, and only 10′ from the pole; consequently it was then the *pole star.* After the lapse of 11,600 years the star *Lyra,* the brightest in the northern hemisphere, will occupy the position of a pole star, being then about 5 degrees from the pole; whereas *now* its north polar distance is upward of 51°.

The mean average precession from the creation (4004 B. C.) to the year 1800, is 49″.51455; consequently the equinoctial points have receded since the creation, 2s. 14° 8′ 27″. The longitude of the star *Beta Arietis*, was in 1820, 31° 27′ 28″: *Meton*, a famous mathematician of Athens, who flourished 430 years before Christ, says, this star, in his time, was in the vernal equinox. If he is correct, then 31° 27′ 28″, divided by 2250 years, the elapsed time, will give 50⅓″ for the precession. Something, however, must be allowed for the imperfection of the instruments used at that day, and even until the sixteenth century.

589. Since all the stars complete half a revolution about the axis of the ecliptic in about 12,500 years, if the *North Star* be at its nearest approach to the pole 250 years hence, it will,

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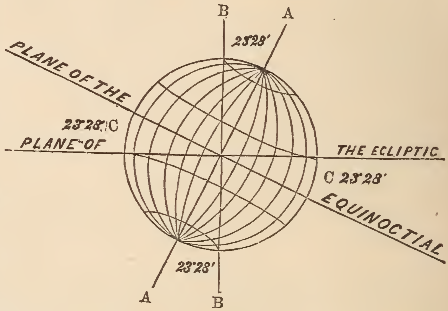
What, then, is the real *pole* of the heavens? 587. Where is the precession of the stars most apparent? Where least? When are the circumpolar stars nearest the tropic of Cancer, and why? 588. Where was the pole star in 1855? When will it be nearest the true pole? How near then? What said of *Alpha Draconis?* Of *Lyra?* Mean average recession for 5800 years? Amount? Longitude of *Beta Arietis* in 1820? Before Christ 430 years, where? Average of precession for these 2250 years? 589. What further result of the revolution of the pole of the heavens? What effect? Where, then, 12,500 years afterwards, be at its greatest possible distance from it, or about 47° above it :—That is, the star itself will remain immovable in its present position, but the pole of the Earth will *then* point as much *below* the pole of the ecliptic, as *now* it points above. This will have the effect, *apparently*, of elevating the present polar star to twice its present altitude, or 47°. Wherefore, at the expiration of half the equinoctial year, that point of the heavens which is now 1° 18′ north of the zenith of Hartford, will be the place of the north pole, and all those places which are situated 1° 18′ north of Hartford, will then have the present pole of the heavens in their zenith.

OBLIQUITY OF THE ECLIPTIC.

590. The inclination of the Earth's axis to the plane of the ecliptic causes the equinoctial to depart 23° 28′ from the ecliptic. This angle made by the equinoctial and the ecliptic is called the *Obliquity of the Ecliptic.*

OBLIQUITY OF THE ECLIPTIC.



Let the line A A represent the axis of the Earth, and B B the poles or axis of the ecliptic. Now if the line A A inclines toward the plane of the ecliptic, or, in other words, departs from the line B B, to the amount of 23° 28′, it is obvious that the plane of the equator, or equinoctial, will depart from the ecliptic to the same amount. This departure, shown by the angles C C, constitute the *obliquity of the ecliptic.*

591. Hitherto, we have considered these great primary circles in the heavens, as never varying their position in space, nor with respect to each other. But it is a remarkable and well-ascertained fact, that both are in a state of constant change. We have seen that the plane of the Earth's equator is constantly drawn out of place by the unequal attraction of the Sun and Moon acting in different directions upon the unequal masses of matter at the equator and the poles ; whereby the intersection of the equator with the ecliptic is constantly retrograding—thus producing the *precession of the equinoxes.*

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will the north pole be 12,500 years hence? 590. What is the *Obliquity of the Ecliptic?* 591. Is this angle always the same? What variation of the equinoctial?

592. The displacement of the *ecliptic*, on the contrary, is produced chiefly by the action of the planets, particularly of Jupiter and Venus, on the Earth ; by virtue of which the plane of the Earth's orbit is drawn nearer to those of these two planets, and consequently, nearer to the plane of the equinoctial. The tendency of this attraction of the planets, therefore, is to *diminish the angle* which the plane of the equator makes with that of the ecliptic, bringing the two planes nearer together ; and if the Earth had no motion of rotation, it would, in time, cause the two planes to coincide. But in consequence of the rotary motion of the Earth, the inclination of these planes to each other remains very nearly the same ; its annual diminution being scarcely more than *three-fourths of one second of a degree.*

The obliquity of the ecliptic, at the commencement of the present century was, according to *Baily*, 23° 27′ 56½″, subject to a yearly diminution of 0″.4755. According to *Bessel*, it was 23° 27′ 54″.32, with an annual diminution of 0″.46. At this date (1855), it is only about 23° 27′ 29″. Consequently, the angle is diminished about 27″ in 55 years. This diminution, however, is subject to a slight semi-annual variation, from the same causes which produce the displacement of the plane of the ecliptic, in precession.

593. The attraction of the Sun and Moon, also, unites with that of the planets, at certain seasons, to augment the diminution of the obliquity, and at other times, to lessen it. On this account the obliquity itself is subject to a periodical variation ; for the attractive power of the Moon, which tends to produce a change in the obliquity of the ecliptic, is *variable*, while the diurnal motion of the Earth, which tends to prevent the change from taking place, is *constant*. Hence the Earth, which is so nicely poised on her center, *bows* a little to the influence of the Moon, and rises again, alternately, like the gentle oscillations of a balance. This curious phenomenon is called *Nutation* (589).

In consequence of the yearly diminution of the obliquity of the ecliptic, the tropics are slowly and steadily approaching the equinoctial, at the rate of little more than three-fourths of a second every year; so that the Sun does not now come so far north of the equator in summer, nor decline so far south in winter, by nearly a degree, as it must have done at the Creation.

594. The most obvious effect of this diminution of the obliquity of the ecliptic, is to equalize the length of our days and nights ; but it has an effect also to change the position of the stars near the tropics. Those which were formerly situated north of the ecliptic, near the summer solstice, are now found to be still farther north, and farther from the plane of the ecliptic. On the contrary, those which, according to the testimony of the

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592. What displacement of the ecliptic, and by what caused? Effect of these causes? Amount of change annually? Obliquity of the ecliptic in 1800? In 1855? 593. Diminution in 55 years? What is *Nutation?* Its *cause?* What effect from this annual diminution of obliquity? 594. What other effect? Will this diminution continue? What

ancient astronomers, were situated south of the ecliptic, near the summer solstice, have approached this plane, insomuch that some are now either situated within it, or just on the north side of it. Similar changes have taken place with respect to those stars situated near the winter solstice. All the stars, indeed, participated more or less in this motion, but *less*, in proportion to their proximity to the equinoctial.

It is important, however, to observe, that this diminution will not always continue. A time will arrive when this motion, growing less and less, will at length entirely cease, and the obliquity will, apparently, remain constant for a time; after which it will gradually increase again, and continue to diverge by the same yearly increment as it before had diminished. This alternate decrease and increase will constitute an endless oscillation, comprehended between certain fixed limits. Theory has not yet enabled us to determine precisely what these limits are, but it may be demonstrated from the constitution of our globe, that such limits exist, and that they are very restricted, probably not exceeding 2° 42′. If we consider the effect of this ever-varying attribute in the system of the universe, it may be affirmed that the plane of the ecliptic never has coincided with the plane of the equator, and never will coincide with it. Such a coincidence, could it happen, would produce upon the Earth perpetual spring.

595. The method used by astronomers to determine the obliquity of the ecliptic is, to take half the difference of the greatest and least meridian altitudes of the Sun.

The following table exhibits the mean obliquity of the ecliptic for every ten years during the present century.

1800	23°	27′	54″.78	1860	23°	27′	27″.86
1810	23	27	50 .21	1870	23	27	22 .79
1820	23	27	45 .64	1880	23	27	18 .22
1830	23	27	41 .07	1890	23	27	13 .65
1840	23	27	36 .50	1900	23	27	09 .08
1850	23	27	31 .93	1910	23	27	04 .52

CHAPTER XIII.

PHILOSOPHY OF THE TIDES.

596. Tides are the alternate rising and falling of the waters of the ocean, at regular intervals. *Flood tide* is when the waters are *rising*; and *ebb* tide, when they are *falling*. The highest and lowest points to which they go are called, respectively, *high* and *low* tides. The tides ebb and flow twice every twenty-four hours—*i. e.*, we have two flood and two ebb tides in that time.

cycle of oscillation? Its probable limits? What conclusion from this oscillation of the ecliptic? 595. By what method do astronomers determine the obliquity of the ecliptic? 596. What are tides? Flood and ebb tides? High and low? How often do they ebb and flow?

597. The tides are not uniform, either as to time or amount. They occur about 50 minutes later every day (as we shall explain hereafter), and sometimes rise much higher and sink much lower than the average. These extraordinary high and low tides are called, respectively, *spring* and *neap* tides.

598. The *cause* of the tides is the attraction of the Sun and Moon upon the water of the ocean. But for this foreign influence, as we may call it, the waters having found their proper level, would cease to heave and swell, as they now do, from ocean to ocean, and would remain calm and undisturbed, save by their own inhabitants and the winds of heaven, from age to age.

NO TIDE.

In this figure, the Earth is represented as surrounded by water, in a state of rest or equilibrium, as it would be were it not acted upon by the Sun and Moon.

599. To most minds, it would seem that the natural effect of the Moon's attraction would be to produce a single tide-wave on the side of the Earth toward the Moon. It is easy, therefore, for students to conceive how the Moon can produce one flood and one ebb tide in twenty four hours.

ONE TIDE-WAVE.

In this cut, the Moon is shown at a distance above the Earth, and attracting the waters of the ocean, so as to produce a high tide at A. But as the moon makes her apparent westward revolution around the Earth but once a day, the simple rising of a flood tide on the side of the Earth toward the moon, would give give us but one flood and one ebb tide in twenty-four hours; whereas it is known that we have two of each.

"The tides," says Dr. Herschel, "are a subject on which many persons find a strange difficulty of conception. That the Moon by her attraction, should heap up the waters of the ocean under her, seems to many persons very natural. That the same cause should, at the same time, heap them up on the opposite side of the Earth (viz., at B in the figure), seems to many palpably absurd. Yet nothing is more true."

600. Instead of a single tide-wave upon the waters of the globe, directly under the Moon, it is found that on the side of the Earth directly opposite, there is another high tide; and that half-way between these two high tides are two low tides. These four tides, viz., two high and two low, traverse the ocean from east to west every day, which accounts for both a flood and an ebb tide every twelve hours.

TWO TIDE-WAVES.

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597. Are the tides uniform? What variation of time? As to amount? What are these extraordinary high and low tides called? 598. The *cause* of tides? How but for this influence? 599. What most obvious effect of the Moon's attraction? Substance of note? Remark of Dr. Herschel? 600. How many tide-waves are there on the globe, and how situated?

In this cut, we have a representation of the tide-waves as they actually exist, except that their height, as compared with the magnitude of the Earth, is vastly too great. It is designedly exaggerated, the better to illustrate the principle under consideration. While the Moon at A attracts the waters of the ocean, and produces a high tide at B, we see another high tide at C on the opposite side of the globe. At the same time it is low tide at D and E.

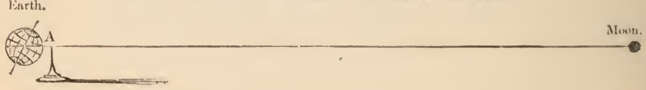
601. The principal cause of the tide-wave on the side of the Earth opposite the Moon is the *difference* of the Moon's attraction on different sides of the Earth.

If the student well understands the subject of gravitation, he will easily perceive how a difference of attraction, as above described, would tend to produce an elongation of the huge drop of water called the Earth. The diameter of the Earth amounts to about $\frac{1}{30}$th of the Moon's distance; so that, by the rule (558), the difference in her attraction on the side of the Earth toward her, and the opposite side, would be about $\frac{1}{18}$th. The attraction being stronger at B (in the last cut) than at the Earth's center, and stronger at her center than at C, would tend to *separate* these three portions of the globe, giving the waters an elongated form, and producing two opposite tide-waves, as shown in the cut.

602. A secondary cause of the tide-wave on the side of the Earth opposite the Moon, is the revolution of the Earth around the common center of gravity between the Earth and Moon, thereby generating an increased centrifugal force on that side of the Earth.

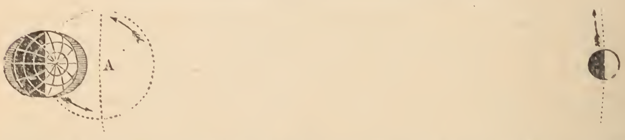
The center of gravity between the Earth and Moon is the point where they would exactly balance each other, if connected by a rod, and poised upon a fulcrum.

CENTER OF GRAVITY BETWEEN THE EARTH AND MOON.



This point which, according to Ferguson, is about 6000 miles from the Earth's center, is represented at A in the above, and also in the next cut.

SECONDARY CAUSE OF HIGH TIDE OPPOSITE THE MOON.



The point A represents the center of gravity between the Earth and Moon; and as it is this point which traces the regular curve of the Earth's orbit, it is represented in the arc of that orbit, while the Earth's center is 6000 miles one side of it. Now, the law of gravitation requires that while both the Moon and Earth revolve around the Sun, they should also revolve around the common center of gravity between them, or around the point A. This would give the Earth a *third revolution*, in addition to that around the

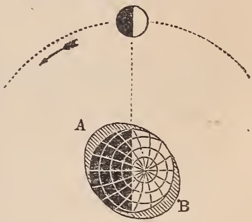
601. State the principal cause of the wave opposite the Moon? Demonstrate by diagram. 602. What other cause operates with the one just stated to produce the tide-wave opposite the Moon? What is the center of gravity between the Earth and the Moon? Where is it situated? Illustrate the operation of this secondary cause.

Sun and on her axis. The small circles show her path around the center of gravity, and the arrows her direction.

This motion of the Earth would slightly increase the centrifugal tendency at B, and thus help to raise the tide-wave opposite the Moon. But as this motion is slow, corresponding with the revolution of the Moon around the Earth, the centrifugal force could not be greatly augmented by such a cause.

603. As the Moon, which is the principal cause of the tides, is revolving eastward, and comes to the meridian later and later every night, so the tides are about 50 minutes later each successive day. This makes the interval between two successive high tides 12 hours and 25 minutes. Besides this daily lagging with the Moon, the highest point of the tide-wave is found to be about 46° behind, or east of the Moon, so that high tide does not occur till about three hours after the Moon has crossed the meridian. The waters do not at once yield to the impulse of the Moon's attraction, but continue to rise after she has passed over.

TIDE-WAVES BEHIND THE MOON.



In the cut, the Moon is on the meridian, but the highest point of the wave is at A, or 45° east of the meridian; and the corresponding wave on the opposite side at B is equally behind.

604. The time and character of the tides are also affected by winds, and by the situation of different places. Strong winds may either retard or hasten the tides, or may increase or diminish their height; and if a place is situated on a large bay, with but a narrow opening into the sea, the tide will be longer in rising, as the bay has to fill up through a narrow gate. Hence it is not usually high tide at New York till eight or nine hours after the Moon has passed the meridian.

605. As both the Sun and Moon are concerned in the production of tides, and yet are constantly changing their positions with respect to the earth and to each other, it follows that they sometimes *act against each other*, and measurably neutralize each other's influence; while at other times they *combine* their forces, and mutually assist each other. In the latter case, an unusually high tide occurs, called the *Spring Tide*. This happens both at new and full Moon.

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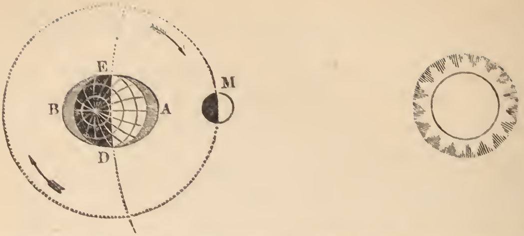
603. What daily lagging of the tides? Interval between two successive high tides? What other lagging? Cause of this last? 604. What modification of the time and character of the tides? 605. Do the Sun and Moon always act together in attracting the waters? Why not? How affect each other's influence? Effect on the tides? What are *Spring Tides?* When do they occur? Illustrate by diagram the cause of spring tides, when the Sun and Moon are in conjunction.

CAUSE OF SPRING TIDES.



Here the Sun and Moon, being in conjunction, unite their forces to produce an extraordinary tide. The same effect follows when they are in opposition; so that we have two spring tides every month—namely, at new and full Moon.

If the tide-waves at A and B are one-third *higher* at the Moon's quadrature than usual, those of C and D will be one-third *lower* than usual.

606. When the Moon is in *quadrature*, and her influence is partly neutralized by the Sun, which now acts against her, the result is a very low tide, called *Neap Tide.*

SPRING AND NEAP TIDES.

The whole philosophy of spring and neap tides may be illustrated by the annexed diagram.

On the right side of the cut, the Sun and Moon are in *conjunction*, and unite to produce a *spring tide.*

At the first quarter, their attraction acts at right angles, and the Sun, instead of contributing to the lunar tide-waves, detracts from it to the amount of his own attractive force. The tendency to form a tide of his own, as represented in the figure, *reduces* the Moon's wave to the amount of one-third.

At the full Moon, she is in *opposition* to the Sun, and their joint attraction acting again in the same line, tends to elongate the fluid portion of the Earth, and a second *spring tide* is produced.

Finally, at the third quarter, the Sun and Moon act *against* each other again, and the second neap tide is the result. Thus we have two spring and two neap tides during every lunation—the former at the Moon's cyzygies, and the latter at her quadratures.

607. Although the Sun attracts the Earth much more powerfully, as a whole, than the Moon does, still the Moon contributes more than the Sun to the production of tides. Their relative influence is as *one* to *three.* The nearness of the Moon makes

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606. What are *Neap Tides?* Their cause? Illustrate entire philosophy by diagram.
607. Comparative influence of Sun and Moon in the production of tides? Why Moon's influence the greatest? Substance of note? Demonstration?

the *difference* of her attraction on different sides of the Earth much greater than the difference of the Sun's attraction on different sides.

It must not be forgotten that the tides are the result not so much of the attraction of the Sun and Moon, *as a whole*, as of the *difference* in their attraction on different sides of the Earth, caused by a difference in the *distances* of the several parts. The attraction being inversely as the square of the distance (558), the influence of the Sun and Moon, respectively, must be in the ratio of the Earth's diameter to their distances. Now the difference in the distance of two sides of the Earth from the Moon is $\frac{1}{30}$th of the Moon's distance; as 240,000÷8,000=30; while the difference, as compared with the distance of the Sun, is only $\frac{1}{11875}$th, as 95,000,000÷8,000=11,875.

608. The tides are subject to another periodic variation, caused by the declination of the Sun and Moon north and south of the equator. As the tendency of the tide-wave is to rise directly under the Sun and Moon, when they are in the south, as in winter, or in the north, as in summer, every alternate tide is higher than the intermediate one.

TIDES AFFECTED BY DECLINATION.

At the time of the equinoxes, the Sun being over the equator, and the Moon within 5½° of it, the crest of the great tide-wave will be on the equator; but as the Sun and Moon decline south to A, one tide-wave forms in the south, as at B, and the opposite one in the north, as at C. If the declination was *north*, as shown at D, the order of the tides would be reversed. The following diagram, if carefully studied, will more fully illustrate the subject of the alternate high and low tides, in high latitudes, in winter and summer:

ALTERNATE HIGH AND LOW TIDES.

Let the line A A represent the plane of the *ecliptic*, and B B the *equinoctial*. On the 21st of June, the day tide-wave is north, and the evening wave south, so that the tide following about three hours after the Sun and Moon, will be higher than the intermediate one at 3 o'clock in the morning.

On the 23d of December, the Sun and Moon being over the southern tropic, the highest wave in the southern hemisphere will be about 3 o'clock P. M, and the lowest about 3 o'clock A.M.; while at the north, this order will be reversed. It is on this account that in high latitudes every alternate tide is higher than the intermediate ones; the evening tides in summer exceeding the morning tides, and the morning tides in winter exceeding those of evening.

609. All spring and neap tides are not alike as to their elevation and depression. As the *distances* of the Sun and Moon are

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608. What other periodic variations mentioned? Explain cause, and illustrate. 609. Are all spring and neap tides alike? By what are they modified? Illustrate by diagram

varied, so are the tides varied, especially by the variations of the Moon.

VARIATIONS IN THE SPRING TIDES.

At A, the Earth is in *aphelion*, and the Moon in *apogee*. As both the Sun and Moon are at their greatest distances, the Earth is least affected by their attraction, and the spring tides are proportionately low.

At B, the Earth is in *perihelion*, and the Moon in *perigee;* so that both the Sun and Moon exert their greatest influence upon our globe, and the spring tides are highest, as shown in the figure. In both cases, the Sun and Moon are in conjunction, but the variation in the *distances* of the Sun and Moon causes variations in the spring tides.

610. In the open ocean, especially the Pacific, the tide rises and falls but a few feet ; but when pressed into narrow bays or channels, it rises much higher than under ordinary circumstances.

The average elevation of the tide at several points on our coast is as follows:

Cumberland, head of the Bay of Fundy	71	feet.
Boston	11¼	"
New Haven	8	"
New York	5	"
Charleston, S. C.	6	"

611. As the great tide-waves proceed from east to west, they are arrested by the continents, so that the waters are permanently higher on their east than on their west sides. The Gulf of Mexico is 20 feet higher than the Pacific Ocean, on the other side of the Isthmus ; and the Red Sea is 30 feet higher than the Mediterranean. Inland seas and lakes have no perceptible tides, because they are too small, compared with the whole surface of the globe, to be sensibly affected by the attraction of the Sun and Moon.

ATMOSPHERICAL TIDES.

612. Air being lighter than water, and the surface of the atmosphere being nearer to the Moon than the surface of the sea, it cannot be doubted but that the Moon raises much higher

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610. Height of tides in open seas? How in narrow bays and channels? Height at different points on our coast ? 611. Direction of tide-waves? What result? Instances cited ? Have inland seas and lakes any tides? Why not ? Remarks respecting philosophy of tides ? 612. Atmospheric tides ?

tides in the atmosphere than in the sea. According to Sir John Herschel these tides are, by very delicate observations, rendered not only sensible, but *measurable.*

Upon the supposition that there is water on the surface of the Moon of the same specific gravity as our own, we might easily determine the height to which the Earth would raise a lunar tide, by the known principle, that the attraction of one of these bodies on the other's surface is *directly* as its quantity of matter, and *inversely* as its diameter. By making the calculation, we shall find the attractive power of the Earth upon the Moon to be 21,777 times greater than that of the Moon upon the Earth.

613. We have thus stated the principal facts connected with this complicated phenomenon, and the *causes* to which they are generally attributed. And yet it is not certain that the philosophy of tides is to this day fully understood. *La Place*, the great French mathematician and astronomer, pronounced it one of the most difficult problems in the whole range of celestial mechanics. It is probable that the atmosphere of our globe has its tides, as well as the waters ; but we have no means, as yet, for definitely ascertaining the fact

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CHAPTER XIV.

THE SEASONS—DIFFERENT LENGTHS OF THE DAYS AND NIGHTS.

614. THE vicissitudes of the seasons, and the unequal lengths of the days and nights, are occasioned by the annual revolution of the Earth around the Sun, with its axis inclined to the plane of its orbit. The temperature of any part of the Earth's surface depends mainly, if not entirely, upon its exposure to the Sun's rays.

INCLINATION OF THE EARTH'S AXIS TO THE PLANE OF THE ECLIPTIC.

615. Whenever the Sun is *above* the horizon of any place, that place is *receiving* heat ; when the Sun is *below* the horizon it is parting with it, by a process which is called radiation. The quantities of heat thus received and imparted in the course of the year, must balance each other at every place, or the equi-

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613. Is it certain that this subject is even yet well understood? Remark of Laplace? 614. Cause of the seasons, and the unequal length of the days and nights? Temperature of the Earth? 615. When does any place *gain* heat, and when lose? Upon what does

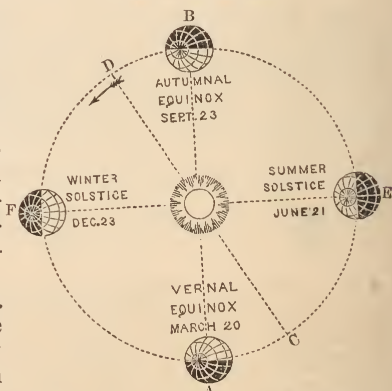
librium of temperature would not be supported. Whenever the Sun remains more than twelve hours above the horizon of any place, and less beneath, the general temperature of that place will be *above* the mean state ; when the reverse takes place, the temperature, for the same reason, will be *below* the mean state. Now, the continuance of the Sun above the horizon of any place, depends entirely upon his declination, or altitude at noon.

616. About the 20th of March, when the Sun is in the vernal equinox, and consequently has no declination, he rises at six in the morning and sets at six in the evening ; the day and night are then equal, and as the Sun continues as long above our horizon as below it, his influence must be nearly the same at the same latitudes, in both hemispheres.

From the 20th of March to the 21st of June, the days grow longer, and the nights shorter, in the northern hemisphere ; the temperature increases, and we pass from spring to midsummer ; while the reverse of this takes place in the southern hemisphere.

From the 21st of June to the 23d of September, the days and nights again approach to equality, and the excess of temperature in the northern hemisphere above the mean state, grows less, as also its defect in the southern ; so that, when the Sun arrives at the autumnal equinox, the mean temperature is again restored.

CAUSE OF THE SEASONS.



617. From the 23d of September until the 21st of December, our nights grow longer and the days shorter, and the cold increases as before it diminished, while we pass from autumn to mid-winter, in the northern hemisphere, and the inhabitants of the southern hemisphere from spring to midsummer.

From the 21st of Dec. to the 20th of March, the cold relaxes as the days grow longer, and we pass from

the length of the days depend? 616. How about the 20th of March? From March 20th to June 21st? From June 21st to September 23d? 617. From September 23d to December 21st? From December 21st to March 20th? How with the seasons in the

the dreariness of winter to the mildness of spring, when the seasons are completed, and the mean temperature is again restored. The same vicissitudes transpire, at the same time, in the southern hemisphere, but in a contrary order. Thus are produced the four seasons of the year.

In the preceding cut, the Earth is shown in her orbit, with her axis inclined 23½°; the North Pole being towards the eye of the student. At A and B the Sun shines from pole to pole, and the days and nights are equal in both hemispheres. On the right, the North Pole is in the light, and we have summer in the northern hemisphere. On the left, the reverse is the case. And the gradual shortening or lengthening of the days, and the change of temperature, are produced by the passage of the Earth from one point to another, with her axis thus inclined.

618. But I have stated not the only, nor, perhaps, the most efficient cause in producing the heat of summer and the cold of winter. If, to the inhabitants of the equator, the Sun were to remain 16 hours below their horizon, and only 8 hours above it, for every day of the year, it is certain they would never experience the rigors of our winter; since it can be demonstrated, that as much heat falls upon the same area from a *vertical* Sun in 8 hours, as would fall from him, at an angle of 60°, in 16 hours.

Now, as the Sun's rays fall *most obliquely when the days are shortest*, and *most directly when the days are longest*, these two causes—namely, the duration and intensity of the solar heat, together, produce the temperature of the different seasons. The reason why we have not the hottest temperature when the days are longest, and the coldest temperature when the days are shortest, but in each case about a month afterwards, appears to be, that a body once heated, does not grow cold instantaneously, but gradually, and so of the contrary. Hence, as long as more heat comes from the Sun by day than is lost by night, the heat will increase, and *vice versâ*.

BEGINNING AND LENGTH OF THE SEASONS.

				h. m. s.	
Sun enters ♑	(Winter begins)	1849,	December 21,	7 25 46	M. T. Wash.
" " ♈	(Spring ")	1850,	March 20,	8 56 38	" "
" " ♋	(Summer ")	"	June 21,	6 3 9	" "
" " ♎	(Autumn ")	"	Sept. 22,	19 58 21	" "
" " ♑	(Winter ")	"	December 21,	13 21 57	" "

southern hemisphere? 618. Is the simple fact that a place is enlightened by the Sun, a sufficient cause for its being warm? What circumstance determines the intensity of the Sun's rays? Why, then, is it not warmest during the longest days, and on the contrary coldest during the shortest days? How long will heat increase?

	d.	h.	m.	s.
Sun in the Winter Signs	89	1	30	52
" " Spring	92	21	6	31
" " Summer	93	13	55	22
" " Autumn	89	17	23	26
" north of Equator (Spring and Summer)	186	11	1	53
" south " (Winter and Autumn)	178	18	54	18
Longest north of the Equator . . .	7	16	7	35
Length of the tropical year beginning at the winter solstice 1849, and ending at the winter solstice 1850.	365	5	56	11
Mean or average length of the tropical year,	365	5	48	48

619. The north pole of the Earth is denominated the *elevated* pole, because it is always about $23\frac{1}{2}°$ above a perpendicular to the plane of the ecliptic, and the south pole is denominated the *depressed* pole, because it is about the same distance below such perpendicular.

As the Sun cannot shine on more than one-half the Earth's surface at a time, it is plain, that when the Earth is moving through that portion of its orbit which lies *above* the Sun, the elevated pole is in the dark. This requires six months, that is, until the Earth arrives at the equinox, when the elevated pole emerges into the light, and the depressed pole is turned away from the Sun for the same period. Consequently, there are six months day and six months night, alternately, at the poles.

620. When the Sun appears to us to be in one part of the ecliptic, the Earth, as seen from the Sun, appears in the point diametrically opposite. Thus, when the Sun appears in the vernal equinox at the first point of Aries, the Earth is actually in the opposite equinox at Libra. The days and nights are then equal all over the world. (See the cut, pages 288 and 292.)

As the Sun appears to move up from the vernal equinox to the summer solstice, the Earth actually moves from the autumnal equinox down to the winter solstice. The days now lengthen in the northern hemisphere, and shorten in the southern. The Sun is now over the north pole, where it is mid-day, and opposite the south pole, where it is midnight. As the Sun descends from the summer solstice towards the autumnal equinox, the Earth ascends from the winter solstice towards the vernal equinox. The summer days in the northern hemisphere having waxed shorter and shorter, now become again of equal length in both hemispheres.

621. While the Sun apears to move from the autumnal equinox down to the winter solstice, the Earth passes up from the vernal equinox to the summer solstice; the south pole comes into the light, the winter days continually shorten in the northern hemisphere, and the summer days as regularly increase in length in the southern hemisphere.

While the Sun appears again to ascend from its winter solstice to the vernal equinox, the Earth descends from the Summer solstice to the autumnal equinox. The summer days now shorten

619. Which is the *elevated* pole, and why? The depressed, and why? How are the seasons produced? 620. How are the Earth and Sun situated in the ecliptic, with reference to each other? What said of the Sun's apparent motion around the zodiac? 621. What further description of the Sun's apparent progress?

in the southern hemisphere, and the winter days lengthen in the northern hemisphere.

622. When the Sun passes the vernal equinox, it rises to the arctic or elevated pole, and sets to the antarctic pole. When the Sun arrives at the summer solstice, it is noon at the north pole, and midnight at the south pole. When the Sun passes the autumnal equinox, it sets to the north pole, and rises to the south pole. When the Sun arrives at the winter solstice, it is midnight at the north pole, and noon at the south pole; and when the Sun comes again to the vernal equinox, it closes the day at the south pole, and lights up the morning at the north pole.

There would, therefore, be 186½ days during which the Sun would not set at the north pole, and an equal time during which he would not rise at the south pole; and 178½ days in which he would not set at the south pole, nor rise at the north pole.

623. At the arctic circle, 23° 27½′ from the pole, the longest day is 24 hours, and goes on increasing as you approach the pole. In latitude 67° 18′ it is 30 days; in lat. 69° 30′ it is 60 days, &c. The same takes place between the antarctic circle and the south pole, with the exception, that the day in the same latitude south is a little shorter, since the Sun is not so long south of the equator, as at the north of it. In this estimate no account is taken of the refraction of the atmosphere, which, as we shall see hereafter, increases the length of the day, by making the Sun appear more elevated above the horizon than it really is. All these apparent motions of the Sun are due to the inclination of the Earth's axis (or the obliquity of the ecliptic), and her revolution around the Sun.

The following cut represents the inclination of the Earth's axis to its orbit in every one of the twelve signs of the zodiac, and consequently for each month in the year. It is such a view as a beholder would have, situated in the north pole of the *ecliptic*, at some distance from it, and consequently, is a perpendicular view, the north pole of the Earth being towards us. The Sun enters the sign *Aries*, or the vernal equinox, on the 20th of March, when the Earth enters *Libra*, and when her axis inclines neither *towards* the Sun, nor *from* it, but stands exactly *sideways* to it; so that the Sun then shines equally upon the Earth from pole to pole, and the days and nights are everywhere equal. This is the beginning of the astronomical year; it is also the beginning of day at the north pole, which is just coming into light and the end of day at the south pole, which is just going into darkness.

By the Earth's orbitual progress, the Sun appears to enter the second sign, *Taurus*, on the 20th of April, when the north pole has sensibly advanced into the light, while the south pole has been declining from it; whereby the days become longer than the nights in the northern hemisphere, and shorter in the southern.

On the 21st of May, the Sun appears to enter the sign *Gemini*, when the north pole

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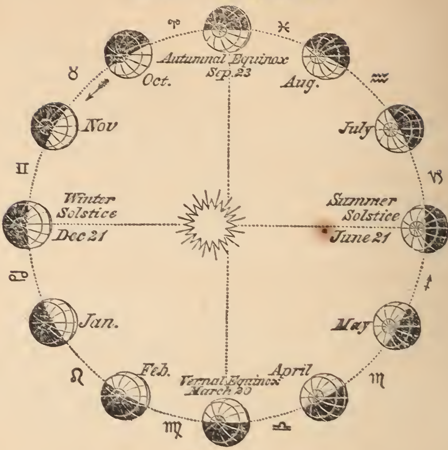
622. How are the light and darkness of the poles affected by the Sun's apparent motion? 623. What said of the length of the days within the arctic circle? In latitude 67° 18′? In latitude 69° 30′? How at the other pole? To what are these various apparent motions of the Sun really due?

PHILOSOPHY OF THE SEASONS.*



has advanced considerably further into the light, while the south pole has proportionally declined from it; the summer days are now waxing longer in the northern hemisphere, and the nights shorter.

The 21st of June, when the Sun enters the sign *Cancer*, is the first day of summer in the astronomical year, and the longest day in the northern hemisphere. The north pole now has its greatest inclination to the Sun, the light of which, as is shown by the boundary of light and darkness, in the figure, extends to the utmost verge of the *Arctic Circle;* the whole of which is included in the enlightened hemisphere of the Earth, and enjoys, at this season, constant day during the complete revolution of the Earth on its axis. The whole of the Northern Frigid Zone is now in the circle of perpetual illumination.

On the 23d of July, the Sun enters the sign *Leo*, and as the line of the Earth's axis always continues parallel to itself, the boundary of light and darkness begins to approach nearer to the poles, and the length of the day in the northern hemisphere, which had arrived at its maximum, begins gradually to decrease. On the 23d of August, the Sun enters the sign *Virgo*, increasing the appearances mentioned in *Leo*.

On the 23d of September, the Sun enters *Libra*, the first of the autumnal signs, when the Earth's axis having the same inclination as it had in the opposite sign, *Aries*, is turned neither *from* the Sun, nor *towards* it, but obliquely to it, so that the Sun again now shines equally upon the whole of the Earth's surface from pole to pole. The days and nights are once more of equal length, throughout the world.

On the 23d of October, the Sun enters the sign *Scorpio;* the days visibly decrease in length in the northern hemisphere, and increase in the southern.

On the 22d of November the Sun enters the sign *Sagittarius*, the last of the autumnal signs, at which time the boundary of light and darkness is at a considerable distance from the north pole, while the south pole has proportionally advanced into the light; the length of the day continues to increase in the southern hemisphere, and to decrease in the northern.

On the 21st of December, which is the period of the winter solstice, the Sun enters the sign *Capricorn*. At this time, the north pole of the Earth's axis is turned from the Sun, into perpetual darkness; while the south pole, in its turn, is brought into the light of the Sun, whereby the whole *Antarctic* region comes into the circle of perpetual illumination. It is now that the southern hemisphere enjoys all those advantages with which the northern hemisphere was favored on the 21st of June; while the northern hemisphere, in its turn, undergoes the dreariness of winter, with short days and long nights.

* This diagram and the accompanying explanations should be carefully studied till they are thoroughly understood by the learner. The cause of the seasons and of the unequal lengths of the days and nights, is a matter of which no professedly educated person ought to be ignorant, or to entertain confused and indefinite notions. By all means let this point be studied till the student can tell the cause of every particular phenomenon of the seasons and the length of the days, without any particular interrogation.

624. By carefully observing the figure, it may be seen that the orbit of the Earth is slightly elliptical, that the Sun is to the left of the center, and that consequently, the Earth is nearer the Sun on the 21st of December, than on the opposite side of the ecliptic, on the 21st of June. This may seem strange to the learner, that we should have our winter when nearest the Sun, and our summer when most distant; but it must be remembered that the temperature of any particular part of the Earth is not so much affected by the *distance* of the Sun, as by the directness or obliquity of his rays. Hence, though we are farther from the Sun on the 21st of June than on the 21st of December, yet, as the north pole of the Earth is turned more directly into the light at that time, so that the Sun's rays strike her surface less obliquely than in December, we have a higher temperature at that period, though at a greater distance from the Sun.

625. The difference, however, between the aphelion and perihelion distances of the Earth is so slight, in comparison with the whole distance, as scarcely to cause a *perceptible* difference in the amount of light received at her respective positions. The eccentricity of the Earth's orbit, or the distance of the Sun from its center, is only about 1,618,000 miles, so that the variation is only 3,236,000 miles, or about *one-thirtieth* of the mean distance. The true orbit of the Earth could not be distinguished from a circle.

The only effect of the eccentricity of the Earth's orbit upon her temperature is, that she has probably a greater degree of heat, during summer in the southern hemisphere, when the Earth is at her perihelion, than we ever have at the north in the same latitude. But this difference must be very slight, if indeed it is at all perceptible.

CHAPTER XV.

THE HARVEST MOON AND HORIZONTAL MOON.

626. The daily progress of the Moon in her orbit, from west to east, causes her to rise, at a mean rate, 48 minutes and 44 seconds later every day than on the preceding. But in places of considerable latitude, a remarkable deviation from this rule

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624. What said of the *form* of the Earth's orbit? When are we nearest the Sun? Why is it not then the warmest in the United States? 625. What is the amount of the Earth's variation in distance from the Sun? What effect upon the light and heat of the Earth? 626. Subject of this chapter? Mean rate of the Moon's daily delay in rising?

takes place, especially about the time of *harvest*, when the full Moon rises to us for several nights together, only from 18 to 25 minutes later in one day, than on that immediately preceding. From the benefit which her light affords, in lengthening out the day, when the husbandmen are gathering in the fruits of the Earth, the full Moon, under these circumstances, has acquired the name of *Harvest Moon.*

It is believed that this fact was observed by persons engaged in agriculture, at a much earlier period than that in which it was noticed by astronomers. The former ascribed it to the goodness of the Deity; not doubting but that he had so ordered it for their advantage.

627. About the equator, the Moon rises throughout the year with nearly the equal intervals of $48\frac{3}{4}$ minutes; and there the harvest Moon is unknown. At the polar circles, the autumnal full Moon, from her first to her third quarter, rises as the Sun sets; and at the poles, where the Sun is absent during one-half of the year, the winter full Moons, from the first to the third quarter, shine constantly without setting.

By this, it is not meant that the Moon *continues full* from her first to her third quarter; but that she *never sets* to the North Polar regions, when, at this season of the year, she is within 90° of that point in her orbit, where she is at her full. In other words, as the Sun illumines the south pole during one-half of its yearly revolution, so the Moon, being *opposite* to the Sun at her full, must illumine the *opposite pole*, during half of her revolution about the Earth. The phenomenon of the Harvest Moon may be thus exemplified by means of the globe.

Rectify the globe to the latitude of the place, put a patch or piece of wafer in the ecliptic, on the point Aries, and mark every 12° preceding and following that point, to the number of ten or twelve marks on each side of it; bring the equinoctial point marked by the wafer to the eastern edge of the horizon, and set the index to 12; turn the globe westward till the other marks successively come to the horizon, and observe the hours passed over by the index; the intervals of time between the marks coming to the horizon, will show the diurnal difference of time between the Moon's *rising*. If these marks be brought to the western edge of the horizon in the same manner, it will show the diurnal difference between the Moon's *setting*.

From this problem it will also appear, that, when there is the least difference between the times of the Moon's *rising*, there will be the greatest difference between the times of her *setting*, and the contrary.

The reason why you mark every 12° is, that the Moon gains 12° 11′ on the apparent course of the Sun every day, and these marks serve to denote the place of the Moon from day to day. It is true, this process supposes that the Moon revolves *in the plane of the ecliptic*, which is not the case; yet her orbit so nearly coincides with the ecliptic (differing only 5° 9′ from it), that they may, for the convenience of illustration, be considered as coinciding; that is, we may take the ecliptic for the representative of the Moon's orbit.

628. The different lengths of the lunar night, at different latitudes, is owing to the different angles made by the horizon and different parts of the Moon's orbit; or, in other words, by the

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What remarkable deviation? What is the Moon then called, and why? How anciently was this phenomenon observed? To what attributed? 627. Is the Harvest Moon known at the equator? How at the Polar circles? At the poles? Does she there exhibit her usual phases? Can you illustrate the phenomenon of the Harvest Moon by a globe? 628. To what is the different lengths of the lunar nights attributable?

Moon's orbit lying sometimes more oblique to the horizon than at others.

In the latitude of London, for example, as much of the ecliptic rises about Pisces and Aries in two hours as the Moon goes through in six days; therefore, while the Moon is in these signs, she differs but two hours in rising for six days together; that is, one day with another, she rises about 20 minutes later every day than on the preceding.

629. The parts or signs of the ecliptic which *rise* with the *smallest* angles, *set* with the *greatest;* and those which rise with the greatest, set with the least. And whenever this angle is least, a greater portion of the ecliptic rises in equal times than when the angle is larger. Therefore, when the Moon is in those signs which rise or set with the smallest angles, she rises or sets with the least difference of time; but when she is in those signs which rise or set with the greatest angles, she rises or sets with the greatest difference of time.

Let the globe, for example, be rectified to the latitude of New York, 40° 42′ 40″, with Cancer on the meridian, and Libra rising in the east. In this position, the ecliptic has a high elevation, making an angle with the horizon of 72⅝°.

But let the globe be turned half round on its axis, till Capricorn comes to the meridian, and Aries rises in the east, then the ecliptic will have a low elevation above the horizon, making an angle with it of only 25⅝°. This angle is 47° less than the former angle, and is equal to the distance between the tropics.

630. In *northern* latitudes, the *smallest* angle made by the ecliptic and horizon is when Aries rises; at which time Libra sets; the *greatest* is, when Libra rises and Aries sets. The ecliptic rises fastest about Aries, and slowest about Libra. Though Pisces and Aries make an angle of only 25½° with the horizon *when they rise*, to those who live in the latitude of New York, yet the same signs, *when they set*, make an angle of 72½°. The daily difference of the Moon's rising, when in these signs, is, in New England, about 22 minutes; but when she is in the opposite signs, Virgo and Libra, the daily difference of her rising is almost four times as great, being about one hour and a quarter

631. As the Moon can never be full but when she is opposite to the Sun, and the Sun is never in Virgo or Libra except in our autumnal months, September and October, it is evident that the Moon is never full in the opposite signs, Pisces and Aries, except in those two months. We can, therefore, have only two full Moons in a year, which rise, for a week together, very near the time of sunset. The former of these is called the *Harvest Moon*, and the latter, the *Hunter's Moon*.

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629. What said of the *angles* under which the signs rise and set? What result follows as to time of the Moon's rising and setting? How illustrate by globe? 630. When is the angle smallest in northern latitudes? When greatest? What difference of angle at the rising and setting of Pisces? Daily difference of the Moon's rising? When in Pisces and Aries? What when in Virgo and Libra? 631. Why have we not more than one *Harvest*, and one *Hunter's* Moon in a year?

632. Although there can be but two *full* Moons in the year that rise with so little variation of time, yet the phenomenon of the Moon's rising for a week together so nearly at the same time, occurs every month, in some part of her course or the other.

In *Winter*, the signs Pisces and Aries rise *about noon;* hence the rising of the Moon is not then regarded nor perceived.

In *Spring*, these signs *rise with the Sun*, because he is then in them; and as the Moon changes while passing through the same sign with the Sun, it must then be *the change*, and hence invisible.

In *Summer*, they rise about midnight, when the Moon, is in her *third* quarter. On account of her rising so late, and giving but little light, her rising passes unobserved.

633. To the inhabitants at the equator, the north and south poles appear in the horizon, and therefore the ecliptic makes the same angle southward with the horizon when Aries rises, as it does northward when Libra rises; consequently the Moon rises and sets not only with angles nearly equal, but at equal intervals of time, all the year round; hence, there is no harvest Moon at the equator. The farther any place is from the equator, if it be not beyond the polar circles, the angle which the ecliptic makes with the horizon gradually diminishes when Pisces and Aries rise.

634. Although, in northern latitudes, the autumnal full Moons are in Pisces and Aries; yet in southern latitudes it is just the reverse, because the seasons are so:—for Virgo and Libra rise at as small angles with the horizon in southern latitudes as Pisces and Aries do in the northern; and therefore the harvest Moons are just as regular on one side of the equator as on the other.

At the polar circles, the full Moon neither rises in summer, nor sets in winter. For the winter full Moon being as high in the ecliptic as the summer Sun, she must continue while passing through the northern signs, *above* the horizon; and the summer full Moon, being as *low* in the ecliptic as the winter Sun, can no more rise, when passing through the southern signs, than he does.

635. The great apparent magnitude of the Moon, and indeed of the Sun, at rising and setting, is a phenomenon which has greatly embarrassed almost all who have endeavored to account for it. According to the ordinary laws of vision, they should appear to be least when nearest the horizon, being then farthest from the eye; and yet the reverse of this is found to be true. The apparent diameter of the Moon, when viewed in the horizon by the naked eye, is two or three times larger than when at the altitude of thirty or forty degrees; and yet when measured by an instrument her diameter is not sensibly increased.

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632. Does not the Moon rise with little variation for several nights in succession, every month? Why not always perceived? 633. Why is there no *Harvest Moon* at the equator? 634. What said of these lunar phenomena in the Southern hemisphere? 635. What said of the apparent diameter of the Moon in the horizon? How when

Both the Sun and the Moon really subtend a greater angle when on the meridian, than they do in the horizon; because they are then actually *nearer* the place of the spectator by the whole semi-diameter of the Earth; and one reason why they appear largest in the horizon is, that they are then compared with terrestrial objects, with whose magnitude we are acquainted.

This apparent increase of magnitude in the horizontal Moon, is chiefly an optical illusion, produced by the concavity of the heavens appearing to the eye to be a less portion of a spherical surface than a hemisphere. The eye is accustomed to estimate the distance between any two objects in the heavens by the quantity of sky that appears to lie between them; as upon the Earth we estimate it by the quantity of ground that lies between them. Now when the Sun or Moon is just emerging above the eastern horizon, or sinking beneath the western, the *distance* of the intervening landscape over which they are seen, contributes, together with the *refraction* of the atmosphere, to exaggerate our estimate of their real magnitudes.

THE HORIZONTAL MOON.

636. Both the Sun and Moon are sometimes seen to be *elongated horizontally*, when near the horizon. This is often the case when the atmosphere is very dense. The cause of this phenomenon is this: All celestial bodies in the horizon are more or less elevated by atmospherical refraction (See page 300); and the *amount* of this apparent elevation depends somewhat upon the *density* of the atmosphere as well as upon the altitude of the object. When, therefore, the Sun or Moon are near the horizon, and viewed through a dense atmosphere, the refraction is greatest; and as their lower limb is seen through a denser stratum of atmosphere than their upper limb, its apparent elevation is greater, and the object seems to be *flattened*, while its horizontal diameter is not sensibly diminished.

This phenomenon and its cause may be easily illustrated by a diagram.

CHAPTER XVI.

REFRACTION AND TWILIGHT.

637. The rays of light, in passing out of one medium into another of a greater density, deviate from a straight course, and are bent towards a perpendicular to that course; and if the density of the latter medium continually increase, the rays of

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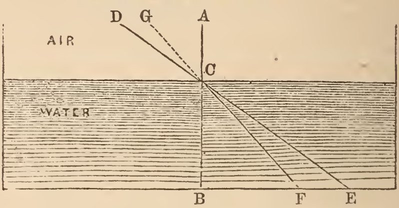
measured? When do they subtend the greater angle? Why appear largest when in the horizon? What other explanation given? 636. What is meant by a *Horizontal* Moon? The cause of this phenomenon? 637. What is meant by the *refraction* of light? What principles govern it?

light in passing through it, will deviate more and more from a right line as they pass downwards, or towards the eye of the observer.

638. As *air* and *water* are both transparent, but of different densities, it follows that, when light passes obliquely from one to the other, it will be refracted. If it pass from the air into the water, it will be refracted *towards a perpendicular*.

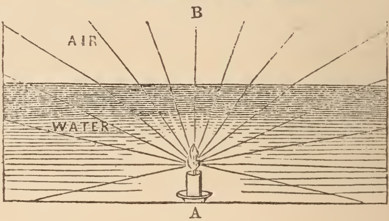
LIGHT REFRACTED BY WATER.



Here the ray A C strikes the water perpendicularly, and passes directly through to B without being refracted. But the ray D C strikes the water at C obliquely; and instead of passing straight through to E, is refracted at C, and reaches the bottom of the water at F. If, therefore, a person were to receive the ray into the eye at F, and to judge of the place of the object from which the light emanates from the direction of the ray C F, he would conclude that he saw the object at G, unless he made allowance for the refraction of the light at C.

639. When light passes obliquely from a denser to a rarer medium, as from water into air, it is refracted *from* a perpendicular towards a horizontal.

LIGHT PROCEEDING FROM WATER.



Here the lamp A shines up through water into air. The ray that strikes the surface perpendicularly passes on to B without being refracted; but the other rays that leave the water obliquely are refracted toward a horizontal direction, in proportion to their distance from the perpendicular; or, in other words, in proportion to the obliquity of their contact with the surface of the water.

640. In consequence of the refraction of light towards a horizontal direction, in passing from water into air, a pole, half of which is in the water, seems bent at the surface, and the lower end seems nearer the surface than it really is. For the same reason, the bottom of a river seems higher, if seen obliquely, than it really is ; and the water is always deeper than we judge it to be.

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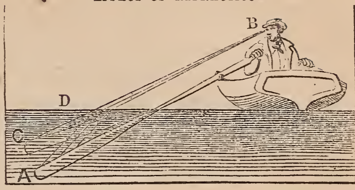
638. How refracted by air and water? 639. How when light passes from denser to rarer media? 640. Effect of refraction upon objects seen under water?

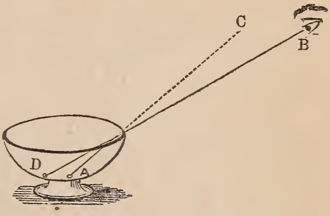
EFFECT OF REFRACTION



In this cut, the *oar*, the blade of which is in the water, seems bent at the surface of the water. The rays of light passing from the part under water to the surface at D, are refracted toward a horizontal direction at that point, and received into the eye of the observer at B, who, judging of the position of the immersed portion of the oar from the direction of the rays D B, locates the blade of the oar at C; thus reversing the effect illustrated at 638.

641. The refracting power of different transparent substances depends mainly upon their density. Water refracts more than air, glass more than water, and diamond most of all. But the angle of incidence, or the obliquity of the contact of the rays with the denser substance, has also much to do in determining the amount of refraction.

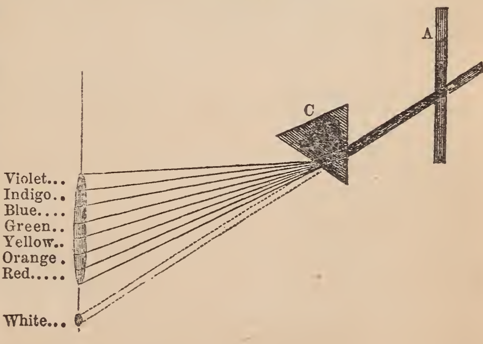
EFFECT OF REFRACTION



642. By the aid of refraction, we may see objects that are actually *behind* an opaque or intransparent body.

Here the piece of money at A, at the bottom of the cup, would be invisible to the beholder at B, if the cup was empty, as the light from the money would pass from A to C; but when the cup is filled with water, the light is refracted to B, and the beholder sees the money apparently at D.

REFRACTION BY A PRISM.



643. By the law of refraction, light has been found to consist of a combination of colors. By passing a beam of light through a triangular piece of flint glass called a *prism*, it is seen that some parts of

641. Upon what does the refracting power of different transparent media depend? 642. What other effect of refraction? 643. What discovery by refraction? How made?

the light are more refrangible than others, so that the light is analyzed, or separated into its component parts or elements.

Let a ray of light from the Sun be admitted through a hole in the window shutter, A, into a room from which all other light is excluded ; it will form on a screen placed a little distance in front, a circular image, B, of white light. Now interpose near the shutter a glass prism, C, and the light, in passing through it, will not only be refracted in the same direction, both when it enters the prism and when it leaves it, but the several rays of which white light is composed will be separated, and will arrange in regular order on the screen, immediately above the image B, which will disappear. The violet ray, it will be seen, is most refracted, and the red least; the whole forming on the scale an elongated image of the Sun, called the *solar spectrum.—Johnston.*

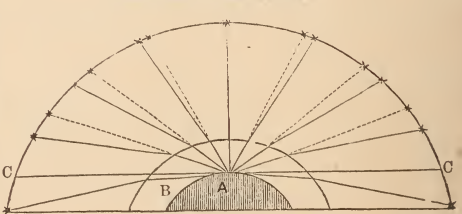
644. It is the refraction of the clouds that gives the sky its beautiful colors morning and evening ; and the refracting power of the rain-drops produces the beautiful phenomenon of the rain-bow.

ATMOSPHERICAL REFRACTION.

645. The refracting power of the atmosphere produces many curious phenomena. Sometimes ships are seen bottom upwards in the air, single or double. At other times, objects really below the horizon, as ships or islands, seem to rise up, and to come distinctly in view.

646. A very important effect of refraction, as it relates to astronomy, is, that it more or less affects the apparent places of all the heavenly bodies. As the light coming from them strikes the atmosphere obliquely, and passes downward through it, it is refracted or bent towward the Earth, or toward a perpendicular. And as we judge of the position of the object by the direction of the ray when it enters the eye, we place objects higher in the heavens than they really are.

ATMOSPHERICAL REFRACTION.



Let A, in the cut, represent the Earth; B, the atmosphere; C C, the visible horizon; and the exterior circle the apparent concave of the heavens. Now, as the light passes from the stars, and strikes the atmosphere, it is seen to curve downward, because it strikes the atmosphere obliquely; and the air increases in density as we approach the Earth. But as the amount of refraction depends not only upon the density, but also upon the obliquity of the contact, it is seen that the refraction is greatest at the horizon, and gradually diminishes till the object reaches the zenith, when there is nc obliquity, and the refrac-

644. What other effects of refraction? 645. Atmospherical refraction? Effects on terrestrial objects? 646. Upon apparent places of stars, &c.?

tion wholly ceases. The dark lines in the cut show the true, and the dotted the apparent positions.

In the cut, the depth of the atmosphere, as compared with the globe, is greatly exaggerated. Even allowing it to be 50 miles deep, it is only $\frac{1}{80}$th of the semi-diameter of the globe, which is equal to only about $\frac{1}{12}$th of an inch upon a common 13-inch globe. But it was necesary to exaggerate, in order to illustrate the principle.

647. The amount of displacement of objects in the horizon, by atmospherical refraction, is about 33′, or a little more than the greatest apparent diameter of either the Sun or Moon. It follows, therefore, that when we see the lower edge of either *apparently* resting on the horizon, its whole disc is in reality below it; and would be entirely concealed by the convexity of the Earth, were it not for refraction.

648. Another effect of refraction is, that the Sun seems to rise about three minutes earlier, and to set about three minutes later, on account of atmospherical refraction, than it otherwise would; thus adding about six minutes, on an average, to the length of each day.

The atmosphere is said to be so dense about the North Pole as to bring the Sun above the horizon some days before he should appear, according to calculation. In 1596, some Dutch navigators, who wintered at Nova Zembla, in latitude 76°, found that the Sun began to be visible 17 days before it should have appeared by calculation; and Kepler computes that the atmospheric refraction must have amounted to 5°, or 10 times as much as with us.

649. The *twilight* of morning and evening is produced partly by refraction, but mainly by reflection. In the morning, when the Sun arrives within 18° of the horizon, his rays pass over our heads into the higher region of the atmosphere, and are thence reflected down to the Earth. The day is then said to be *dawn*, and the light gradually increases till sunrise. In the evening, this process is reversed, and the twilight lingers till the Sun is 18° below the horizon. There is thus more than an hour of twilight both morning and evening.

In the arctic regions, the Sun is never more than 18° below the horizon; so that the twilight continues during the whole night.

650. In making astronomical observations, for the purposes of navigation, &c., allowance has to be made for refraction, according to the altitude of the object, and the state of the atmosphere. For this purpose tables are constructed, showing the amount of refraction for every degree of altitude, from the horizon to the zenith.

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647. Amount of displacement of celestial objects by refraction? What follows? 648. Influence of refraction on length of days? How about the North Pole? 649. Cause of *twilight?* 650. What allowance for refraction? Tables?

CHAPTER XVII.

AURORA BOREALIS AND PARALLAX.

651. The sublime and beautiful phenomena presented by the *Aurora Borealis*, or *northern lights*, as they are called, have been in all ages a source of admiration and wonder alike to the peasant and the philosopher. In the regions of the north (and indeed in many other places) they are regarded by the ignorant with superstitious dread, as harbingers of evil; while all agree in placing them among the unexplained wonders of nature.

These lights, or meteoric coruscations, are more brilliant in the arctic regions, appearing mostly in the winter season and in frosty weather. They commonly appear at twilight near the horizon, and sometimes continue in that state for several hours without any sensible motion; after which they send forth streams of stronger light, shooting with great velocity up to the zenith, emulating, not unfrequently, the lightning in vividness, and the rainbow in coloring; and again, silently rising in a compact majestic arch of steady white light, apparently durable and immovable, and yet so evanescent, that while the beholder looks upon it, it is gone.

At other times they cover the whole hemisphere with their flickering and fantastic coruscations. On these occasions their motions are amazingly quick, and they astonish the spectator with rapid changes of form. They break out in places where none were seen before, skimming briskly along the heavens; then they are suddenly extinguished, leaving behind an uniform dusky track, which, again, is brilliantly illuminated in the same manner, and as suddenly left a dull blank. Some nights they assume the appearance of vast columns; exhibiting on one side tints of the deepest yellow, and on the other, melting away until they become undistinguishable from the surrounding sky. They have generally a strong tremulous motion from end to end, which continues till the whole vanishes.

652. *Maupertius* relates, that in Lapland, "the sky was sometimes tinged with so deep a red that the constellation Orion looked as though it were dipped in blood, and that the people fancied they saw armies engaged, fiery chariots, and a thousand prodigies." *Gmelin* relates, that, "in Siberia, on the confines of the icy sea, the spectral forms appear like rushing armies; and that the hissing, crackling noises of those aerial fireworks so terrify the dogs and the hunters, that they fall prostrate on the ground, and will not move while the raging host is passing."

Kerguelen describes "the night between *Iceland* and the *Ferro* Islands, as brilliant as the day"—the heavens being on fire with flames of red and white light, changing to columns and arches, and at length confounded in a brilliant chaos of cones, pyramids, radii, sheaves, arrows, and globes of fire.

653. But the evidence of *Captain Parry* is of more value

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651. What said of the *Aurora Borealis?* How regarded by the ignorant? Where most brilliant? In what weather? Describe? 652. Observations of *Maupertius*, *Gmelin*, and *Kerguelen?* 653. Observations of *Capt. Parry?*

than that of the earlier travelers, as he examined the phenomena under the most favorable circumstances, during a period of twenty-seven consecutive months, and because his observations are uninfluenced by imagination. He speaks of the shifting figures, the spires and pyramids, the majestic arches, and the sparkling bands and stars which appeared within the arctic circle, as surpassing his powers of description. They are, indeed, sufficient to enlist the superstitious feelings of any people not fortified by religion and philosophy.

654. The *colors* of the polar lights are of various tints. The *rays* or *beams* are steel grey, yellowish grey, pea green, celandine green, gold yellow, violet blue, purple, sometimes rose red, crimson red, blood red, greenish red, orange red, and lake red. The *arches* are sometimes nearly black, passing into violet blue, grey, gold yellow, or white bounded by an edge of yellow. The *luster* of these lights varies in kind as well as intensity. Sometimes it is pearly, sometimes imperfectly vitreous, sometimes metallic. Its degree of intensity varies from a very faint radiance to a light nearly equaling that of the Moon.

655. Many theories have been proposed to account for this wonderful phenomenon, but there seems to be none which is entirely satisfactory. One of the first conjectures on record attributes it to inflammable vapors ascending from the Earth into the polar atmosphere, and there ignited by electricity. Dr. Halley objects to this hypothesis, that the cause is inadequate to produce the effect. He was of opinion that the poles of the Earth were in some way connected with the aurora; that the Earth was hollow, having within it a magnetic sphere, and that the magnetic effluvia, in passing from the north to the south, might become visible in the northern hemisphere.

656. That the aurora borealis is, to some extent, a magnetical phenomenon, is thought, even by others, to be pretty clearly established by the following considerations:

(1.) It has been observed, that when the aurora appears near the northern horizon in the form of an arch, the middle of it is not in the direction of the true north, but in that of the magnetic needle at the place of observation; and that when the arch rises towards the zenith, it constantly crosses the heavens at right angles, not to the true *magnetic* meridian.

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654. What said of the *colors*, &c., of these polar lights? 655. Is there a satisfactory explanation of these phenomena? What conjecture? Dr. Halley's objection? His own singular opinion? 656. What evidences that the *Aurora Borealis* is of magnetic origin?

(2.) When the beams of the aurora shoot up so as to pass the zenith, which is sometimes the case, the point of their convergence is in the direction of the prolongation of the dipping needle at the place of observation.

(3.) It has also been observed, that during the appearance of an active and brilliant aurora, the magnetic needle often becomes restless, varies sometimes several degrees, and does not resume its former position until after several hours.

From these facts, it has been generally inferred that the aurora is in some way connected with the magnetism of the Earth; and that the simultaneous appearance of the meteor, and the disturbance of the needle, are either related as cause and effect, or as the *common result* of some more general and unknown cause.

657. Dr. Young, in his lectures, is very certain that the phenomenon in question is intimately connected with electro-magnetism, and ascribes the *light* of the aurora to the illuminated agency of electricity upon the magnetical substance.

It may be remarked, in support of the electro-magnetic theory, that in magnetism, the agency of electricity is now clearly established, and it can hardly be doubted that the phenomena both of electricity and magnetism are produced by one and the same cause; inasmuch as magnetism may be induced by electricity, and the electric spark has been drawn from the magnet.

658. Sir John Herschel also attributes the appearance of the aurora to the agency of electricity. This wonderful agency, says he, which we see in intense activity in lightning, and in a feebler and more diffused form traversing the upper regions of the atmosphere in the northern lights, is present, probably, in immense abundance in every form of matter which surrounds us, but becomes sensible, only when disturbed by excitements of peculiar kinds.

PARALLAX OF THE HEAVENLY BODIES.

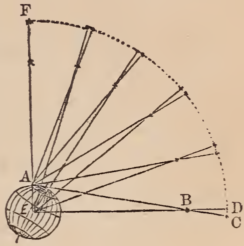
659. Parallax is the difference between the altitude of any celestial object seen from the Earth's surface, and the altitude of the same object seen at the same time from the Earth's center; or it is the angle under which the semi-diameter of the Earth would appear, as seen from the object.

The *true place* of a celestial body is that point of the heavens in which it would be seen by an eye placed at the center of the Earth. The *apparent place* is that point of the heavens where the body is seen from the surface of the Earth. The parallax

657. Dr. Young's opinion? What remark in support of his views? 658. Sir John Herschel's opinion? 659. Parallax? True place of a celestial body? Apparent? When parallax greatest? Least? Called what, and why? What objects the greatest parallax?

of a heavenly body is greatest when in the horizon, and is thence called the *horizontal parallax.* Parallax decreases as the body ascends towards the zenith, at which place it is nothing.

PARALLAX OF THE PLANETS.



The adjoining cut will afford a sufficient illustration. When the observer, standing upon the Earth at A, views the object at B, it appears to be at C, when, at the same time, if viewed from the center of the Earth, it would appear to be at D. The parallax is the angle B C D or A B E, which is the difference between the altitude of the object B, when seen from the Earth's surface, and when seen from her center. It is also the angle under which the semi-diameter of the Earth, A E, is seen from the object B.

As the object advances from the horizon to the zenith, the parallax is seen gradually to diminish, till at F it has no parallax, or its apparent and true place are the same.

This diagram will also show why objects *nearest* the Earth have the *greatest* parallax, and those most distant the least; why the Moon, the nearest of all the heavenly bodies, has the greatest parallax; while the fixed stars, from their immense distance, have no appreciable horizontal parallax—the semi-diameter of the Earth, at such a distance, being no more than a point.

660. As the effect of parallax on a heavenly body is to depress it *below its true place*, it must necessarily affect its right ascension and declination, its latitude and longitude. On this account, the parallax of the Sun and Moon must be *added* to their *apparent* altitude, in order to obtain their *true* altitude.

The true altitude of the Sun and Moon, except when in the zenith, is always affected, more or less, both by parallax and refraction, but always in a contrary manner. Hence the mariner, in finding the latitude at sea, always *adds* the parallax, and *subtracts* the refraction, to and from the Sun's *observed* altitude, in order to obtain the *true* altitude, and thence the latitude.

661. The principles of parallax are of great importance to astronomy, as they enable us to determine the distances of the heavenly bodies from the Earth, the magnitudes of the planets and the dimensions of their orbits.

The Sun's horizontal parallax being accurately known, the Earth's distance from the Sun becomes known; and the Earth's distance from the Sun being known, that of all the planets may be known also, because we know the exact periods of their sidereal revolutions, and, according to the third law of Kepler, the squares of the times of their revolutions are proportional to the cubes of their mean distances. Hence, the first great desideratum in astronomy, where measure and magnitude are concerned, is the determination of the true parallax.

At a council of astronomers assembled in London some years since, from the most

660. Effect of parallax? How obtain true altitude? How differ from refraction? How then obtain true altitude? 661. Use of parallax? How employed? Note?

learned nations in Europe, the Sun's mean horizontal parallax was settled, as the result of their united observations, at 0° 0′ 8″.5776. Now the value of radius, expressed likewise in seconds, is 206264″.8; and this divided by 8″.5776, gives 24047 for the distance of the Sun from the the Earth, in semi-diameters of the latter. If we take the *equatorial* semi-diameter of the Earth, as sanctioned by the same tribunal, at (7924÷2=) 3962 miles, we shall have 24047 × 3962=95,273,869 miles for the Sun's true distance.

A TABLE OF THE SUN'S PARALLAX IN ALTITUDE.

Sun's Altit.	*Sun's Horizontal Parallax.*					*Sun's Altit.*	*Sun's Horizontal Parallax.*				
°	″ 8.4	″ 8.5	″ 8.6	″ 8.7	″ 8.8	°	″ 8.4	″ 8.5	″ 8.6	″ 8.7	″ 8.8
0	8.40	8.50	8.60	8.70	8.80	45	5.94	6.01	6.08	6.15	6.22
5	8.37	8.47	8.57	8.67	8.77	50	5.40	5.46	5.53	5.59	5.66
10	8.27	8.37	8.47	8.57	8.67	55	4.82	4.88	4.93	4.99	5.05
15	8.11	8.21	8.31	8.40	8.50	60	4.20	4.25	4.30	4.35	4.40
20	7.89	7.99	8.08	8.18	8.27	65	3.55	3.59	3.63	3.68	3.72
25	7.61	7.70	7.79	7.88	7.98	70	2.87	2.91	2.94	2.98	3.01
30	7.28	7.36	7.45	7.53	7.62	75	2.17	2.20	2.23	2.25	2.28
35	6.88	6.96	7.04	7.13	7.21	80	1.46	1.48	1.49	1.51	1.53
40	6.44	6.51	6.59	6.66	6.74	85	0.73	0.74	0.75	0.76	0.77
45	5.94	6.01	6.08	6.15	6.22	90	0.00	0.00	0.00	0.00	0.00

662. The change in the apparent position of the fixed stars, caused by the change of the Earth's place in her revolution around the Sun, is called their *annual parallax.* So immense is their distance, that the semi-annual variation of 190,000,000 of miles in the Earth's distance, from all those stars that lie in the plane of her orbit, makes no perceptible difference in their apparent magnitude or brightness.

The following cut will illustrate our meaning:

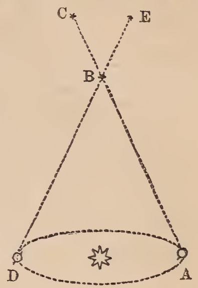
Let A represent a fixed star in the plane of the Earth's orbit, B. At C, the Earth is 190,000,000 of miles nearer the star than it will be at D six months afterward; and yet this semi-annual variation of 190,000,000 miles in the distance of the star is so small a fraction of the whole distance to it, as neither to increase or diminish its apparent brightness.

663. It is only those stars that are situated near the axis of the Earth's orbit whose parallax can be measured at all, on

662. What meant by Earth's *annual parallax?* Effect of variation of Earth's distance on the fixed stars? Diagram. 663. What stars have perceptible parallax?

account of its almost imperceptible quantity. So distant are they, that the variation of 190,000,000 miles in the Earth's place causes an apparent change of less than 1′ in the nearest and most favorably situated fixed star.

PARALLAX OF THE STARS.



Let A represent the Earth on the 1st of January, and B a star observed at that time. Of course, its apparent place in the more distant heavens will be at C. But in six months the Earth will be at D, and the star B will appear to be at E. The angle A B D or C B E will constitute the parallactic angle. In the cut, this angle amounts to about 48°, whereas the real parallax of the stars is less than $\frac{1}{60}$th of one degree, or $\frac{1}{2900}$th part of this amount. Lines approaching each other thus slowly would appear parallel; and the Earth's orbit, if filled with a globe of fire, and viewed from the fixed stars, would appear but a point of light 1′ in diameter! For a splendid diagram illustrative of the annual parallax of the stars, see Map I., of the Atlas.

ABERRATION OF LIGHT.

664. In the year 1725, Mr. Molyneux and Dr. Bradley fixed up a very accurate and costly instrument, in order to discover whether the fixed stars had any sensible parallax, while the Earth moved from one extremity of its orbit to the other; or which is the same, to determine whether the nearest fixed stars are situated at such an immense distance from the Earth, that any star which is seen this night, directly north of us, will, six months hence, when we shall have gone 190,000,000 of miles to the eastward of the place we are now in, be then seen exactly north of us still, without changing its position so much as the thickness of a spider's web.

665. These observations were subsequently repeated, with but little intermission, for twenty years, by the most acute observers in Europe, and with telescopes varying from 12 feet to 36 feet in length. In the mean time, Dr. Bradley had the honor of announcing to the world the very nice discovery made while endeavoring to ascertain the parallax of the fixed stars, that *the motion of light, combined with the progressive motion of the Earth in its orbit, causes the heavenly bodies to be seen in a different position from what they would be, if the eye were at rest.* Thus was established the principle of the *Aberration of Light.*

666. This principle, or law, now that it is ascertained, seems

Amount? Diagram, and explanation. 664. What experiment by Molyneux and Bradley? With what results? 665. What further observations for the same purpose? What discovery made while investigating the subject of parallax? What is the *aberration of light?* 666. What remarks upon the *principle* or *law* of observation? How is not only very plain, but self-evident. For if light be progressive, the position of the telescope, in order to receive the ray, must be different from what it would have been if light had been instantaneous, or if the Earth stood still. Hence the place to which the telescope is directed will be different from the true place of the object.

The quantity of this aberration is determined by a simple proposition. The Earth describes 59′ 8″ of her orbit in a day =3548″, and a ray of light comes from the Sun to us in 8′ 13″ =493″ : now 24 hours or 86400″ : 493 : : 3548 : 22″; which is the change in the star's place, arising from the cause abovementioned.

CHAPTER XVIII.

PRACTICAL ASTRONOMY—REFLECTION AND REFRACTION OF LIGHT.

667. *Practical Astronomy* has respect to the *means* employed for the acquisition of astronomical knowledge. It includes the properties of light, the structure and use of instruments, and the processes of mathematical calculation.

In the present treatise, nothing further will be attempted than a mere introduction to practical astronomy. In a work designed for popular use, mathematical demonstrations would be out of place. Still, every student in astronomy should know how telescopes are made, upon what laws they depend for their power, and how they are used. It is for this purpose mainly that we add the following chapters on practical astronomy.

PROPERTIES OF LIGHT.

668. *Light* is that invisible ethereal substance by which we are apprised of the existence, forms, and colors of material objects, through the medium of the visual organs. To this subtile fluid we are especially indebted for our knowledge of those distant worlds that are the principal subjects of astronomical inquiry.

669. The term *light* is used in two different senses. It may signify either light itself, or the *degree* of light by which we are enabled to see objects distinctly. In this last sense, we put light

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the *quantity* of aberration determined? 667. Subject of Chapter XVIII.? What is *practical astronomy?* How far discussed in this treatise? 668. Define light. For what indebted to it? 669. Different senses in which the term is used? What is in opposition to darkness. But it should be borne in mind, that *darkness* is merely the absence of that *degree* of light which is necessary to human vision; and when it is dark to us, it may be light to many of the lower animals. Indeed, there is more or less light, even in the darkest night, and in the deepest dungeon.

"Those unfortunate individuals," says Dr. Dick, "who have been confined in the darkest dungeons, have declared, that though, on their first entrance, no object could be perceived, perhaps for a day or two, yet, in the course of time, as the pupils of their eyes expanded, they could readily perceive rats, mice, and other animals that infested their cells, and likewise the walls of their apartments; which shows that, even in such situations, light is present, and produces a certain degree of influence."

670. Of the *nature* of the substance we call light, two theories have been advanced. The first is, that the whole sphere of the universe is filled with a subtile fluid, which receives from luminous bodies an *agitation;* so that, by its continued vibratory motion, we are enabled to perceive luminous bodies. This was the opinion of Descartes, Euler, Huygens, and Franklin.

The second theory is, that light consists of particles thrown off from luminous bodies, and actually proceeding through space. This is the doctrine of Newton, and of the British philosophers generally.

Without attempting to decide, in this place, upon the relative merits of these two hypotheses, we shall use those terms, for convenience sake, that indicate the actual passage of light from one body to another.

671. Light proceeds from luminous bodies in straight lines, and in all directions. It will not wind its way through a crooked passage, like sound; neither is it confined to a part of the circumference around it.

As the Sun may be seen from every point in the solar system, and far hence into space in every direction, even till he appears but a faint and glimmering star, it is evident that he fills every part of this vast space with his beams. And the same might be said of every star in the firmament.

672. As vision depends not upon the *existence* of light merely, but requires a certain *degree* of light to emanate from the object, and to enter the pupil of the eye, it is obvious that if we can, by any means, *concentrate* the light, so that more may enter the eye, it will improve our perception of visible objects, and even enable us to see objects otherwise wholly invisible.

Some animals have the power of adapting their eyes to the existing degree of light. The cat, horse, &c., can see day or night; while the owl, that sees well in the night, sees poorly in the day-time.

673. Light may be turned out of its course either by *reflection*

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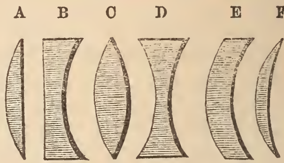
darkness? Can it be dark and light at the same time? Is there any place without light? Quotation from Dr. Dick? 670. What theories of the *nature* of light, and by whom supported respectively? Remark of author? 671. How light proceeds from luminous bodies? Radiations from Sun and stars? 672. How improve vision, and why? Animals? 673. How is light turned out of its course?

or *refraction.* It is *reflected* when it falls upon the highly polished surface of metals and other intransparent substances; and *refracted* when it passes through transparent substances of different densities, as already illustrated in Chapter XVI.

REFRACTION BY GLASS LENSES.

674. A *lens* is a piece of glass, or other transparent substance, of such a form as to collect or disperse the rays of light that are passed through it, by refracting them out of a direct course. They are of different forms, and have different powers.

LENSES OF DIFFERENT FORMS.



In the adjoining cut, we have an edgewise view of six different lenses.

A is the *plano-convex*, or half a double convex lens; one side being convex and the other plane.

B is a *plano-concave;* one surface being concave, and the other plane.

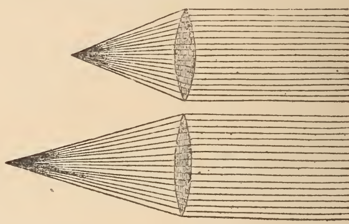
C is a *double-convex* lens, or one that is bounded by two convex surfaces.

D is a *double-concave* lens, or a circular piece of glass hollowed out on both sides.

E is a *concavo-convex* lens, whose curves differ, but do not meet, if produced.

F is a *meniscus*, or a concavo-convex lens, the curves of whose surfaces meet.

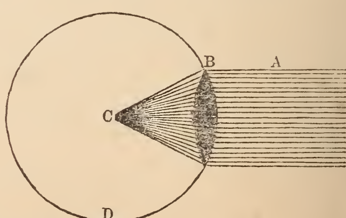
LIGHT REFRACTED BY LENSES.



675. A *double-convex* lens converges parallel rays to a point called the *focus;* and the distance of the focus depends upon the degree of convexity.

In the first of these cuts, the lens is quite thick, and the focus of the rays is quite near; but the other being less convex, the focus is more distant.

DOUBLE CONVEX—FOCAL DISTANCE.



676. The distance of the focus of a *double-convex* glass lens is the radius of the sphere of its convexity.

In this cut, it will be seen that the parallel rays A are refracted to a focus at C, by the double-convex lens B, the convexity of whose surfaces is just equal to the curve of the circle D.

677. The focal distance of a *plano-convex* lens is equal to the diameter of the sphere formed by the convex surface produced.

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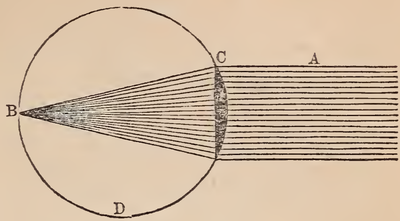
674. What is a *lens?* Draw and describe different kinds. 675. Refracting power of *double-convex* lens? Focal distance? Diagram, and illustrate. 676. How focal distance governed? Diagram, and illustrate. 677. What is the focal distance of a

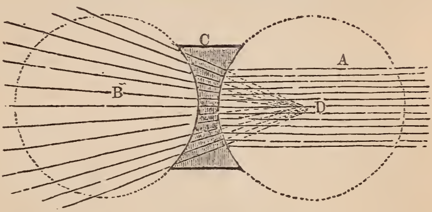
PLANO-CONCAVE—FOCAL DISTANCE.



It must be borne in mind, that light is refracted both when it enters, and when it leaves a double convex lens, and in both instances in the same direction; and, so far as the distance of the focus is concerned, to the same extent. But when the lens is convex only on one side, half its refracting power is gone, so that the rays are not so soon refracted to a focus. In this case, the focal distance is equal to the *diameter* of the sphere formed by extending the convex surface of the lens; while with the double-convex lens, the focal distance is only equal to the *radius* of such sphere. In the cut, the parallel rays A are refracted to a focus at B, by the plano-concave lens C; and the distance C B is the diameter of the circle D, formed by the convex surface of the lens C produced.

678. A *double-concave* lens *disperses* parallel rays, as if they diverged from the center of a circle formed by the convex surface produced.

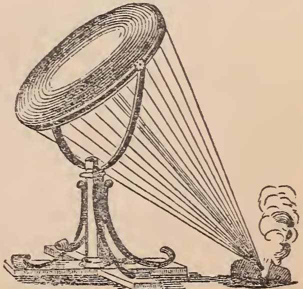
RAYS DISPERSED BY REFRACTION.



In this cut, the parallel rays A are dispersed by the double-concave lens C, as shown at B; and their direction, as thus refracted, is the same as if they proceeded from the point D, which is the center of a circle formed by the concave surface of the lens produced.

679. Common spectacles, opera-glasses, burning-glasses, and refracting telescopes are made by converging light to a focus, by the use of double-convex lenses.

BURNING-GLASS.



The ordinary burning-glass, which may be bought for a few shillings, is a double-convex disk of glass two or three inches in diameter, inclosed in a slight metallic frame, with a handle on one side. Old tobacco-smokers sometimes carry them in their pockets, to light their pipes with when the Sun shines. In other instances, they have been so placed, as to fire a cannon in clear weather, by igniting the priming at 12 o'clock.

The adjoining cut represents a large burning-glass converging the rays of the Sun to a focus, and setting combustible substances on fire. Such glasses have been made powerful enough to melt the most refractory substances, as platinum, agate, &c. "A lens three feet in diameter," says Professor Gray, "has been known to melt cornelian in 75 seconds, and a piece of white agate in 30 seconds."

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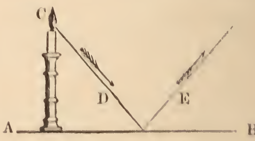
plano-convex lens? Diagram. 678. Effect of *double-convex* lens? Amount of divergency of rays? 679. What articles made with double-convex lenses? Uses? Powe. of burning glasses?

REFLECTION OF LIGHT.

680. We have now shown how light may be turned out of its course, and analyzed, dispersed, or converged to a point by *refraction.* Let us now consider how it may be converged to a focus by *reflection.*

When light falls upon a highly-polished surface, especially of metals, it is *reflected* or thrown off in a new direction, and the angles of contact and departure are always equal.

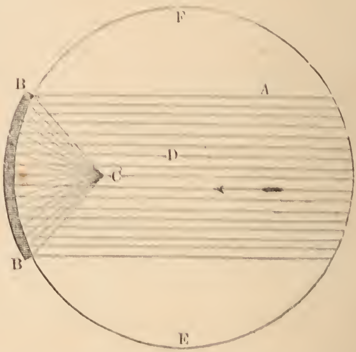
REFLECTION BY A PLANE MIRROR.



Let A B represent the polished metallic surface, C the source of light, and the arrows the direction of the ray. Then D would represent the angle of incidence or contact, and E the angle of reflection or departure—which angles are seen to be equal.

681. A *concave mirror* reflects parallel rays back to a focus, the distance of which is equal to half the radius of the sphere formed by the concave surface produced.

REFLECTION BY A CONCAVE MIRROR.



In this cut, the parallel rays A fall upon the concave mirror B B, and are reflected to the focus C, which is half the radius of the sphere formed by the surface of the mirror produced. If, therefore, it was desirable to construct a concave mirror, having its focus 10 feet distant, it would only be necessary to grind it on the circle of a sphere having a radius of 20 feet.

682. In reflection, a portion of the light is absorbed or otherwise lost, so that a reflector of a given diameter will not converge as much light to a focus as a double-convex lens of the same size. In the latter case all the light is transmitted. Still, reflectors have been found of such power as to melt iron, and other more difficult substances.

We have now considered so much of optics as is necessary to an understanding of the principles upon which telescopes are constructed; and, for further particulars, shall refer the student to books on Natural Philosophy.

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680. What now shown in this chapter? What next? What is *reflection*, and when does it take place? What law governs it? Diagram. 681. How does a *concave* mirror reflect parallel rays? Distance of focus? Diagram. How would you construct a concave mirror with a 10 feet focus? 682. Is all the light falling upon a polished surface reflected? What then? Closing note?

CHAPTER XIX.

TELESCOPES—REFRACTORS AND REFLECTORS.

683. A TELESCOPE is an optical instrument employed in viewing distant objects, especially the heavenly bodies. The term *telescope* is derived from two Greek words, viz., *tele*, at a distance, and *skopeo*, to see. So far as is now known, the ancients had no knowledge of the telescope. Its invention, which occurred in 1609, is usually attributed to *Galileo*, a philosopher of Florence, in Italy.

The discovery of the principle upon which the refracting telescope is constructed was purely accidental. The children of one *Jansen*, a spectacle-maker of Middleburgh, in Holland, being at play in their father's shop, happened to place two glasses in such a manner, that in looking through them, at the weathercock of the church, it appeared to be nearer, and much larger than usual. This led their father to fix the glasses upon a board, that they might be ready for observation; and the news of the discovery was soon conveyed to the learned throughout Europe. Galileo hearing of the phenomenon, soon discovered the secret, and put the glasses in a *tube*, instead of on a board; and thus the first telescope was constructed.

684. The telescope of Galileo was but one inch in diameter, and magnified objects but 30 times. Yet with this simple instrument he discovered the face of the Moon to be full of inequalities, like mountains and valleys; the spots on the Sun; the phases of Venus; the satellites of Jupiter; and thousands of new stars in all parts of the heavens.

Notwithstanding this propitious commencement, so slow was the progress of the telescope towards its present state, that in 1816, Bonnycastle speaks of the 30-fold magnifying power of the telescope of Galileo as "nearly the greatest perfection that this kind of telescope is capable of!"

685. If he be the real author of an invention who, from a knowledge of the cause upon which it depends, deduces it from one principle to another, till he arrives at the end proposed, then the whole merit of the invention of the telescope belongs to *Galileo*. The telescope of *Jansen* was a rude instrument of mere curiosity, accidentally arranged; but *Galileo* was the first who constructed it upon principles of science, and showed the practical uses to which it might be applied.

It is said that the original telescope constructed by Galileo is still preserved in the British Museum. A pigmy, indeed, in its way, but the honored progenitor of a race of giants!

686. The discovery of the telescope tended greatly to sustain

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683. Subject of Chapter XIX.? Telescope? Derivation? Ancient or modern? Inventor? Incidents of discovery? 684. Galileo's telescope? Discoveries with it? Progress in telescope making? 685. Is Galileo entitled to the honor of inventing the telescope? Where is his? 686. Relation of discovery to Copernican theory? Effects

the Copernican theory, which had just been promulgated, and of which Galileo was an ardent disciple. Like Copernicus, how ever, his doctrines subjected him to severe persecutions, and he was obliged to renounce them.

The following is his renunciation, made June 28, 1633: "I, Galileo, in the seventieth year of my age, on bended knees before your eminences, having before my eyes and touching with my hands the Holy Gospels, I curse and detest the error of the Earth's movement." As he left the court, however, after this forced renunciation, he is said to have stamped upon the Earth, and exclaimed, "It does move, after all?" Ten years after this, he was sent to prison for the same supposed error; and soon, his age advancing, the grave received him from the malice of his persecutors.

DIFFERENT KINDS OF TELESCOPES.

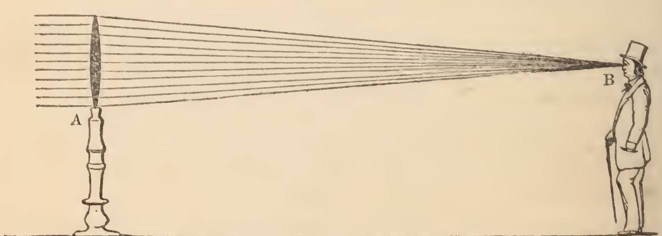
687. Telescopes are of two kinds—*Reflectors* and *Refractors*. Refracting telescopes are made by *refracting* the light to a focus with a glass lens (675); and reflecting telescopes, by *reflecting* it to a focus with a concave mirror (681). Besides this general division, there are various kinds both of reflectors and refractors.

Telescopes assist vision in various ways—first, by enlarging the visual angle under which a distant object is seen, and thus magnifying that object; and, secondly, by converging to a point more light than could otherwise enter the eye—thus rendering objects distinct or visible that would otherwise be indistinct or invisible.

All the light falling upon a six or a twelve inch lens may be converged to a focus, so as to be taken into the human eye through the pupil, which is but one-fourth of an inch in diameter. Our vision is thus made as perfect by art as if nature had given us ability to enlarge the eye till the pupil was a foot in diameter.

688. Refracting telescopes may consist of a double-convex lens placed upon a stand, without tube or eye-piece. Indeed, a pair of ordinary spectacles is nothing less than a pair of small telescopes, for aiding impaired vision.

REFRACTING TELESCOPE WITH A SINGLE LENS.

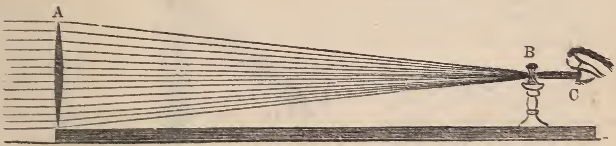


Here the parallel rays are seen to pass through the lens at A, and to be so converged to a point as to enter the eye of the beholder at B. His eye is thus virtually enlarged to the size of the lens at A. But it would be very difficult to direct such a telescope toward celestial objects, or to get the eye in the focus after it was thus directed.

upon Galileo? His renunciation? Death? 687. Kinds of telescopes? Describe. How assist vision? Illustration. 688. Simplest form of refracting telescope?

689. The *Galilean telescope* consists of two glasses—a *double-convex* next the object, and a double-concave near the eye. The former converges the light till it can be received by a small double-concave, by which the convergency is corrected (502), and the rays rendered parallel again, though in so small a beam as to be capable of entering the eye.

GALILEAN TELESCOPE.



Here the light is converged by the lens A, till it can be received by the double-concave lens B, by which the rays are made to become a small parallel beam that can enter the eye at C. This was the form of the telescope constructed by *Jansen*, and improved by Galileo; on which account it is called the *Galilean telescope*. In the cut, the two lenses are represented as fastened to a *board*, as first exhibited by Jansen.

690. The common astronomical telescope consists of two glasses—viz., a large double-convex lens next the object, called the *object-glass;* and a small double-convex lens or microscope next the eye, called the *eye-piece*. For the greater convenience in using, they are both placed in a tube of wood or metal, and mounted in various ways, according to their size, and the purposes to which they are devoted.

LENSES PLACED IN A TUBE.

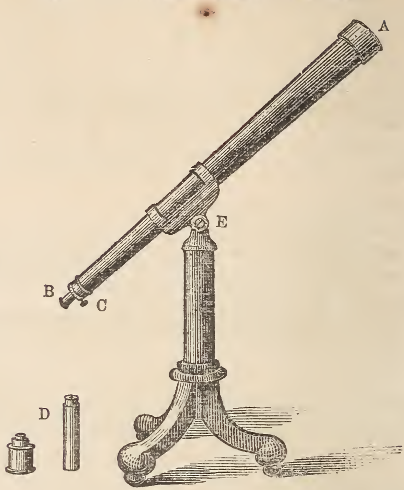
A is the *object-glass*, B the *eye-piece*, and C the place where the tube, in which the eye-piece is set, slides in and out of the large tube, to adjust the eye-piece to the focal distance. By placing the lenses in a tube, the eye is easily placed in the focus, and the object-glass directed toward any desired object.

691. The object-glass of a telescope is usually protected, when not in use, by a brass cap that shuts over the end of the instrument; and the eye-pieces, of which there are several, of differ-

689. *Galilean* telescope? Why called *Galilean?* 690. How common astronomical telescopes made? Why in tube? 691. How object-glass protected? What said of eye-pieces?

ent magnifying powers, are so fixed as to screw into a small movable tube in the lower end of the instrument, so as to adjust them respectively, to the focus, and to the eyes of different observers. Such telescopes usually represent objects in an inverted position.

REFRACTING TELESCOPE MOUNTED ON A STAND.



The adjoining cut represents the simplest form of a mounted refractor. The object-glass is at A, where the brass cap may be seen covering it. B is the small tube into which the eye-piece is screwed, and which is moved in and out by the small screw C. Two eye-pieces may be seen at D—one short one, for astronomical observations, and a long one, for land objects. For viewing the Sun, it is necessary to add a screen, made of colored glass. At E, a bolt goes into a socket in the top of the stand, in which it turns, allowing the telescope to sweep around the horizon; while the joint, connecting the saddle in which the telescope rests with the top of the bolt, allows it to be directed to any point between the horizon and the zenith. But such stands answer only for comparatively small instruments.

692. Refracting telescopes are mounted in various ways. So important is it that they should not shake or vibrate, that, in most observatories, the stand rests upon heavy mason-work in no way connected with the building, so that neither the wind nor the tread of the observer can shake it. They are then furnished with a double axis, which allows of motion up and down, or east and west; and two graduated circles show the precise amount of declination and right ascension.

They are often furnished with clockwork, by which the telescope is made to move westward just as fast as the Earth turns eastward; so that the celestial object being once found, by setting the instrument for its right ascension and declination, or by the aid of the *Finder*—a small telescope attached to the lower end of the large one—it may be kept in view by the clockwork for any desirable length of time. A telescope thus furnished with right ascension and declination circles is called an *Equatorial*, or is said to be *equatorially mounted*, because it sweeps east and west in the heavens parallel to the equator.

693. The object-glasses of telescopes are not always made of a single piece of glass. They may be made of two concavo-convex glasses, like two watch crystals, with their concave sides

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692. How refractors mounted, and why? When equatorial, and why? 693. How object-glasses made? What a *lens?* A *Barlow* lens?

towards each other, or with a thin double concave glass between them. They are thus double, or triple; but when thus constructed, the whole is called a *lens*, as if composed of a single piece.

Lenses have also been formed by putting two concavo-convex glasses together, and filling the space between them with some transparent fluid. These are called *Barlow* lenses, from Prof. Barlow, their inventor.

694. As a prism analyzes the light, and exhibits different colors, so a double convex lens may analyze the light that falls near its circumference, and thus represent the outside of the heavenly bodies as colored. But this defect is remedied by using discs made of different kinds of glass, so as to correct one refraction by another. Refracting telescopes thus corrected are called *Achromatic* telescopes.

Achromatic is from the Greek *a chroma*, which signifies destitute of color. Most refracting telescopes are now so constructed as to be achromatic.

695. It is but recently that any good refracting telescopes have been made in this country. The best have formerly been made in Germany and France; but they are now manufactured with success, and to considerable extent, by Mr. Henry Fitz, Jun., New York City. The glass used by him is obtained from Paris, because none suitable for large telescopes has yet been made in America. His telescopes are perfectly achromatic, and are sold much cheaper than imported ones of the same size and value.

Mr. Fitz has recently made a very valuable improvement in the mounting of telescopes—one which is not only much superior to the old method, but which costs only about one-half as much. This improvement consists in using a single piece of cast-iron in the place of several pieces of brass work. It is very simple, secures great steadiness to the instrument, and is easily adjusted.

The writer is fully satisfied of the value of this improvement, and would recommend it, as well as Mr. Fitz's instruments, to all institutions and amateur astronomers about to purchase either. Besides patronizing a worthy American optician, they will get as good a telescope and much better mounting than by sending abroad, and at far less expense The following is a list of telescopes manufactured by Mr. Fitz, with the prices attached:

PRICES OF FITZ'S TELESCOPES, EQUATORIALLY MOUNTED, ETC.

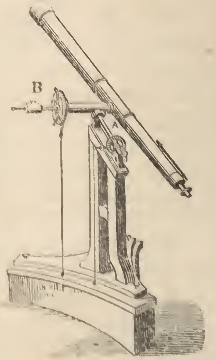
Focal Length.	Object Glass.	New Style Mounting.	Old Style Mounting.	Difference of Cost.
9 ft.	8½ inches.	$1,400	$2,300	$900
11 "	8¼ "		2,220	
10 " 8 inch.	8 "	1,500	2,000	850
8 "	6⅔ "	700	1,200	500
7 "	5 "	400	750	850
7 "	4½ "	300	500	200
5 "	4 "	225	400	175

694. What is an *Achromatic* telescope? Derivation of term? 695. Where telescopes formerly made? Where and by whom now, in this country? Where is the glass obtained? What said of Mr. Fitz's telescopes?

He will furnish a very good telescope of three inches aperture for $120, equatorially mounted, with eye-pieces, &c. The size priced at $225, is equal to that at Yale College. A good revolving dome for an observatory building can be built for $100.

This note is inserted exclusively for the benefit of institutions using the work, and without any request or remuneration from Mr. Fitz. Orders or letters of inquiry may be addressed to Henry Fitz, Jun., 237 Third-street, New York.

A FITZ REFRACTOR.



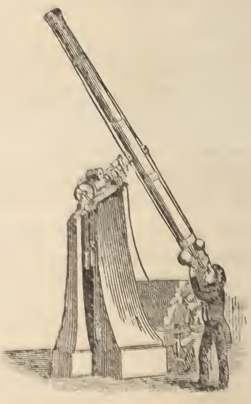
696. The adjoining cut represents an equatorial telescope manufactured by Mr. Henry Fitz of New York—the one used by the author in making most of his observations. Its object-glass is six inches in diameter, and its focal length eight feet. It is perfectly achromatic, and performs all the tests laid down in Dick's Practical Astronomer, as evidence of a good instrument, with perfect ease. Under favorable circumstances, it shows the sixth star in the trapezium of Orion, and to show Polaris double is a very easy test indeed.

A is the declination circle, and B the circle of right ascension. The two sticks hanging from these circles are used to move the instrument in right ascension or declination, while the observer is at the eye-piece.

The *Finder* is seen attached to the lower end of the large instrument. It takes in a larger field of view in the heavens than the latter, and enables the observer to look up objects with facility, and bring them into the field of the larger instrument.

This instrument has no clockwork attached. It rests upon a pillar of heavy masonwork, the top of which may be seen in the cut; and in the hands of its present owner, Lewis M. Rutherford, Esq., has already rendered very efficient service.

REFRACTING TELESCOPE AT CINCINNATI, OHIO.



697. The adjoining cut represents one of the largest telescopes in the United States. It is located in the observatory on Mount Adams, near Cincinnati, Ohio, and was for a time under the direction of *Prof. Mitchel*, by whose instrumentality it was purchased and mounted.

The object-glass is about 12 inches in diameter, with a focal distance of 17 feet. It was purchased in Munich, Germany, in 1844, at an expense of nearly *ten thousand dollars.* There is but one larger than this in the United States, and but two larger in the world.

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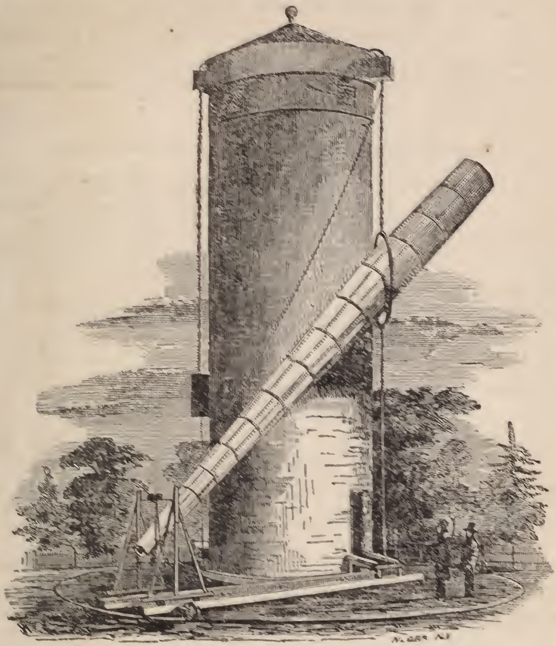
696. Mr. Rutherford's Telescope? By whom made? 667. Cincinnati refractor—where located? By whom purchased? Where? When? Cost? Size and focal distance? Comparative size?

THE GREAT CRAIG TELESCOPE, WANDSWORTH COMMON, NEAR LONDON.



698. This is the largest refracting telescope ever constructed The object-glass is two feet in diameter, with a focal distance of 76 feet. The tube is of heavy sheet iron, and shaped somewhat like a cigar. It is 13 feet in circumference in the largest place, and weighs about three tons.

This telescope is suspended from a brick tower, 65 feet high, 15 feet in diameter, and weighing 220 tons. The top of the tower, from which the telescope is suspended, revolves; and by a chain running over pulleys, and a weight and windlass, it is balanced, and raised or lowered. The lower end rests on a small carriage, that runs upon a circular railroad around the tower, at the distance of 52 feet from its center. By these means it is directed to almost any point in the heavens. It is called the "Craig" telescope, in honor of the Rev. Mr. Craig, under whose direction, and at whose expense, it was constructed. It is located at Wandsworth Common, near London.

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698. Describe the Craig telescope. Object glass? Focal distance? Tube? How mounted? Why called "Craig" telescope? Where located?

699. Besides this monster refractor, there are several other very fine instruments in Europe; as the Dorpat telescope, Sir James South's, the Northumberland refractor, the Oxford telescope, &c. Several colleges and seminaries in the United States have observatories connected with them, and telescopes of greater or less value. The largest is at Cambridge, near Boston.

PUBLIC OBSERVATORIES AND TELESCOPES IN THE UNITED STATES.

Observatories.	When procured.	THEIR TELESCOPES. Name of maker.	Focal length. ft.	in.	Aperture of object-glass. inches.	Cost.
Yale College	1830	Dollond.	10	—	5	$1,000
Wesleyan University	1836	Lerebours.	7	—	6	1,000
Williams College	1836	Holcomb.	10	—	reflector.	
	1852	A. Clark.	9	—	7	
Hudson, Ohio	1837	Simms.	5	6	4	
Philadelphia	1840	Merz.	8	4	6⅜	1,900
West Point	1841	Lerebours.	8	—	6	
Washington	1844	Merz.	15	3	9·6	6,000
Cincinnati	"	"	17	—	12	9,437
Cambridge	1846	"	22	6	15	19,842
Dartmouth College	1848	"	9	—	6·4	
Georgetown "	1849	Simms.	7	6	4·8	1,600
Erskine "	"	Fitz.	7	—	5·6	1,050
Shelby "	1850	Merz.	10	4	7·5	3,500
Columbia (S. C.) College	1851	Fitz.	8	4	6⅜	1,200
Columbia (Mo.)	1852	"	5	—	4	225

700. Quite a number of very respectable *private* observatories are also in operation in different parts of the country. The following table includes most of them:

PRIVATE OBSERVATORIES.

Owner and Location.	TELESCOPES. When procured.	Maker.	Focal length. ft.	in.	Object-glass. inches.	Cost.
J. Jackson, near Philadelphia	1846	——	8	4	6 3-10	$1,833
Mr. Longstreet, Philadelphia	"	Fitz.	7	—	5	900
S. G. Gummere, Burlington, N. J.	1847	"	5	—	4	425
R. Vanarsdale, Newark, N. J.	1850	"	7	—	5	750
	1851	"	8	4	6⅜	1,000
W. S. Van Duzee, Buffalo, N. Y.	"	"	11	—	8¼	2,220
W. S. Dickie, Elkton, Ky.	"	"	6	—	4½	300
D. Mosman, Bangor, Me.	"	"	5	—	4	225
J. Campbell, New York	1852	"	10	—	8	1,150

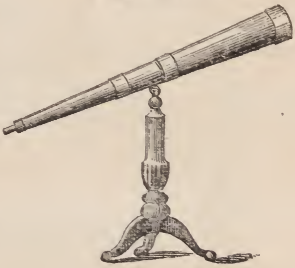
699. What other refractors in Europe besides the Craig? Public observatories in this country? Largest telescope? Table? 700. Private observatories—names? Telescopes—by whom mostly made? What other table?

The following is a list of the principal foreign observatories, with their latitude and longitude. The longitude is from Greenwich, near London.

FOREIGN OBSERVATORIES—THEIR LATITUDE AND LONGITUDE.

Observatories.	Latitude.				Longitude in Time.			
	°	′	″		h.	m.	s.	
Altona	53	32	45	N.	0	39	46.2	E.
Armagh	54	21	12.7	N.	0	26	35.5	W.
Berlin	52	30	16.7	N.	0	53	34.9	E.
Brussels	50	51	10.7	N.	0	17	27.2	E.
Cambridge	52	12	51.8	N.	0	0	23.5	E.
Cape of Good Hope	33	56	3	S.	1	13	56.0	E.
Copenhagen	55	40	53	N.	0	50	19.8	E.
Dorpat	58	22	47.1	N.	1	46	54.6	E.
Dublin	53	23	13	N.	0	25	22	W.
Edinburgh	55	57	23.2	N.	0	12	43.0	W.
Göttingen	51	31	47.9	N.	0	39	46.1	E.
Greenwich	51	28	38.2	N.	0	0	0.0	
Königsberg	54	42	50.4	N.	1	22	0.4	E.
Munich	48	8	45	N.	0	46	26.4	E.
Palermo	38	6	44	N.	0	53	25.5	E.
Paris	48	50	13	N.	0	9	21.5	E.
Petersburg	59	56	29.7	N.	2	1	13.5	E.
Rome	41	53	54	N.	0	49	54.7	E.
Turin	45	4	6	N.	0	30	48.4	E
Vienna	48	12	35.5	N.	1	5	32.6	E.

A COMET SEEKER.



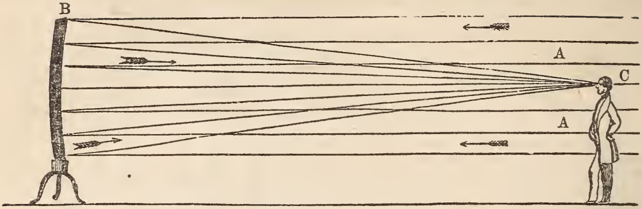
701. A *Comet Seeker* is a refracting telescope with a large aperture and short focal distance. As comets cannot be found by their right ascension and declination, but often have to be searched up, by sweeping around the heavens with a telescope, before they become visible to the naked eye, it is important to have telescopes that will cover considerable space—that is, of wide aperture and short focal distance. Such a telescope was made by Mr. Fitz for Miss Mitchel, of Newport, R. I

REFLECTING TELESCOPES.

702. The *Reflecting Telescope* is one in which the light is converged to a focus by means of a concave metallic reflector or speculum. Like the *Refractors*, they may be constructed with very little mounting ; though for convenience in use, it is necessary to place the reflector in a tube.

701. What is a *comet seeker?* Why necessary? 702. Describe a reflecting telescope. Simplest form?

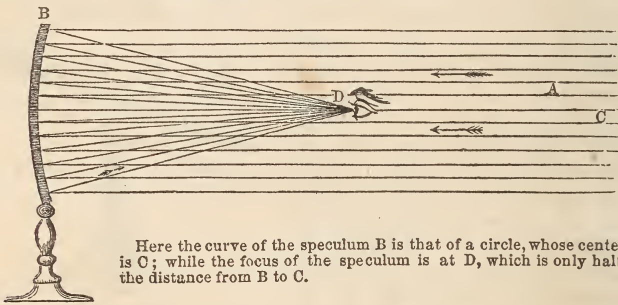
SIMPLEST FORM OF A REFLECTING TELESCOPE



In this cut, the light A is seen passing from the object on the right, and falling upon the concave surface of the reflector at B, from which it is reflected back to a focus, and enters the eye of the observer at C. This telescope has no eye-piece.

703. The focal distance of a concave reflector is equal to half the radius of the sphere formed by the concave surface produced. Hence to grind a reflector for a focus of 20 feet, it will be necessary to have the curve that of a circle whose radius is 40 feet.

FOCAL DISTANCE OF A CONCAVE REFLECTOR.

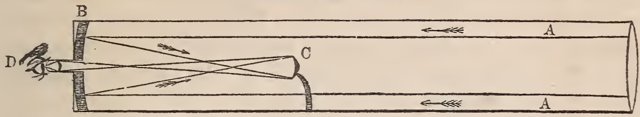


Here the curve of the speculum B is that of a circle, whose center is C; while the focus of the speculum is at D, which is only half the distance from B to C.

704. Reflecting telescopes are of several kinds—viz., the *Gregorian*, the *Newtonian*, the *Cassegranian*, the *Herschelian*, &c. The *Gregorian Reflector* has an aperture in the center of the speculum, and a small concave mirror in the focus of the speculum, which reflects the light back through the aperture to the eye-piece. In this way the observer is enabled to face the object, and to direct the telescope toward it, as if it were a refractor.

703. Focal distance? 704. How many kinds of reflectors? Describe the Gregorian. Why called Gregorian?

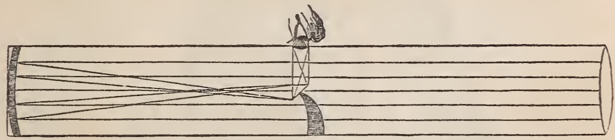
GREGORIAN REFLECTOR.



Here the light A falls upon the speculum at B, and is reflected back to the small mirror C, by which it is thrown out through the aperture in the speculum, to the eye of the observer at D. The object is supposed to be off on the right, in the direction towards which the instrument is pointed. It is called a *Gregorian* telescope, after Mr. James Gregory, who first suggested the construction of reflecting telescopes.

705. The *Newtonian Reflector* is so called after Sir Isaac Newton, its inventor. Instead of a concave mirror in the focus of the speculum, he placed a plane mirror there, inclined so as to reflect the light to the *side* of the tube, where it was received by the observer.

NEWTONIAN REFLECTOR.

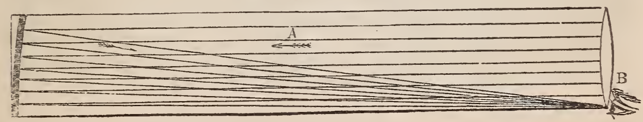


The light from the speculum is here shown falling upon the inclined mirror in the center, and reflected out to the eye of the observer.

706. The *Cassegranian Reflector* is so called from M. Cassegrain, its inventor. It resembles the Gregorian, except that the speculum placed in the focus of the reflector is *convex* instead of concave.

The *Herschelian Reflector* differs from all others, in having no small reflector whatever ; the light being reflected back to a focus at the top of the telescope, and near the edge of the tube, where the eye-piece is placed, and where the observer sits looking into the mirror with his back to the object

HERSCHELIAN TELESCOPE.

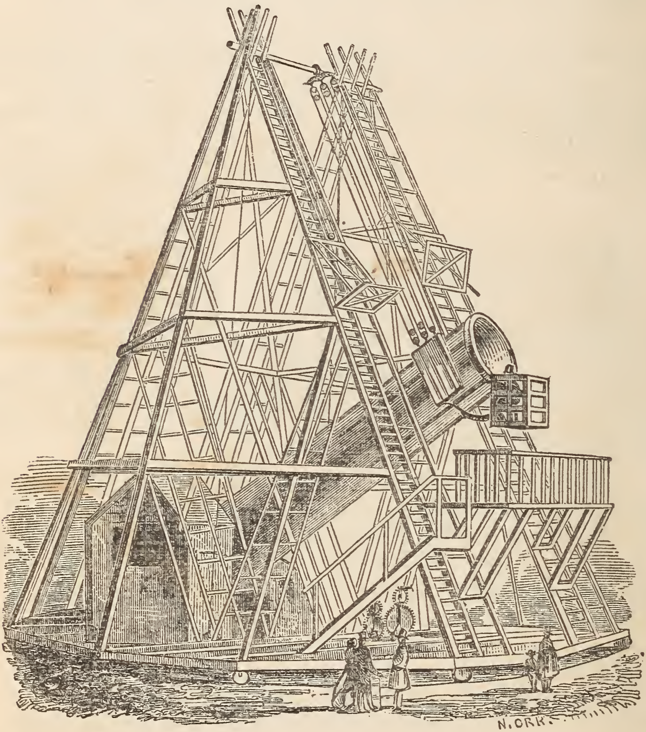


Here the concave speculum is seen to be inclined a little to the lower side of the tube, so that the parallel rays A are reflected back to the observer at B, at the side of the instrument, where the eye-piece is placed.

705. Newtonian reflectors? 706. Cassegranian? Difference? Herschelian? Where eye-piece? How observer sit?

707. The first telescope constructed upon this plan was that by Sir William Herschel, in 1782. This was called his 20 feet reflector, and was the instrument with which he made many of his observations upon the double stars. In 1789, he completed his *forty feet* reflector, until recently the largest telescope ever constructed.

SIR WILLIAM HERSCHEL'S FORTY FEET REFLECTOR.



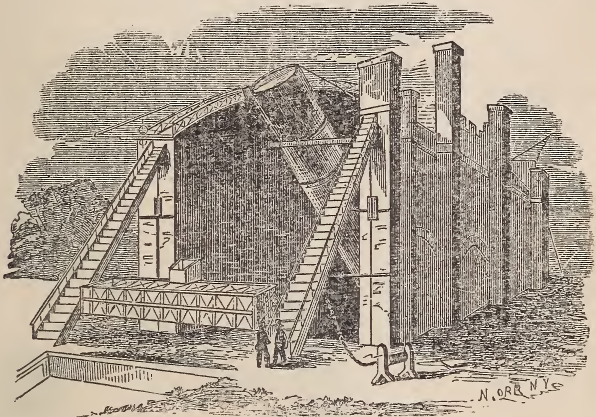
708. The speculum of this instrument is 4 feet in diameter, 3½ inches thick, and weighed, before being ground, 2,118 pounds.

707. First Herschelian telescope? What called? Next? 708. Herschel's forty feet reflector? Size of Speculum? Weight? Tube? Length and weight? How mounted?

The tube is made of sheet iron riveted together, and painted within and without.

The length of the tube is 39 feet 4 inches, and its weight 8,260 pounds. It is elevated or lowered by tackles, attached to strong frame-work; and the observer, who sits in a chair at the upper end of the tube, and looks down into the reflector at the bottom, is raised and lowered with the instrument. Three persons are necessary to use this telescope—one to observe, another to work the tube, and a third to note down the observations. A speaking tube runs from the observer to the house where the assistants are at work. By this telescope, the sixth and seventh satellites of Saturn were discovered; and it was the chief instrument used by its distinguished owner, in making the observations and discoveries which have immortalized his name, and which have so abundantly enriched and advanced the science of astronomy.

LORD ROSSE'S GREAT REFLECTING TELESCOPE.



709. This is the largest reflecting telescope ever constructed. The speculum, composed of copper and tin, weighed three tons as it came from the mould, and lost about $\frac{1}{8}$th of an inch in grinding. It is $5\frac{1}{2}$ inches thick, and 6 feet in diameter. It was cast on the 13th of April, 1842, and was cooled gradually in an oven for 16 weeks, to prevent its cracking, by a sudden or unequal reduction of the temperature. This speculum has a reflecting surface of 4071 square inches. The tube is made of deal wood, one inch thick, and hooped with iron. Its diameter is seven feet, and its length 56.

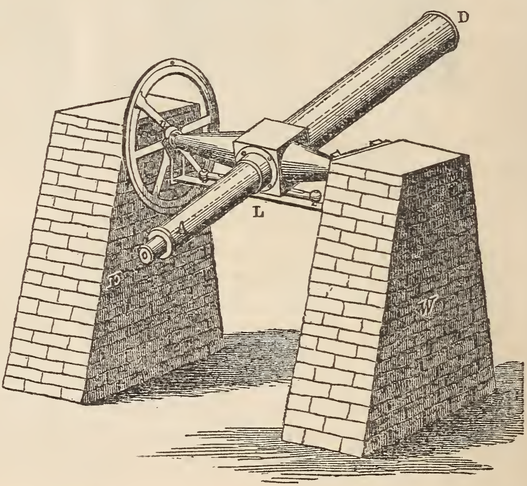
The entire weight of this telescope is twelve tons. It is mounted between two north and south walls, 24 feet apart, 72 feet long, and 48 feet high. The lower end rests upon an universal hinge. It can be lowered to the horizon, and raised to the zenith, and lowered northward till it takes in the Pole Star. Its motion from east to west is limited

Observer where? Usefulness? 709. Lord Rosse's telescope? Weight of speculum? Diameter? Thickness? Cooling? Tube? Entire weight? How mounted? What to 15 degrees. This magnificent instrument is situated at Burr Castle, Ireland. It was constructed by the Earl of Rosse, at an expense of $60,000.

Speaking of this telescope, a late writer says: "By the energy and ingenuity of that eminent person (Lord Rosse), an eye is directed to the heavens, having a pupil six feet in diameter, with the most complete optical structure, and the power of ranging about for its objects over a great extent of sky; and thus the quantity of light which the eye secures from any point of the heavens is augmented, it may be, *fifty thousand times.* The rising Moon is seen from the Observatory in Ireland with the same increase of size and light, as if her solid globe, two thousand miles in diameter, retaining all its illumination, really rested upon the summit of the Alps, to be gazed at by the naked eye. An object which appears to the naked eye a single star may, by this telescope, so far as its power of seeing is concerned, be resolved into fifty thousand stars, each of the same brightness as the obvious star.*

710. A *Transit Instrument* is a telescope used for observing the transit of celestial objects across the meridian, for the purpose of determining differences of right ascension, or obtaining correct time. They are usually from six to ten feet long, and are mounted upon a horizontal axis, between two abutments of mason-work; so that the instrument, when horizontal, will point exactly to the south. It will then take objects in the heavens, when they are exactly on the meridian.

A TRANSIT INSTRUMENT.



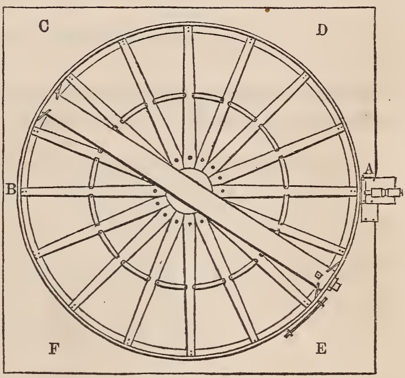
Let A D in the cut represent the telescope, and E and W the east and west abutments, between which it is placed. On the left is seen, attached to the mason work, a graduated circle; and on the eastern end of the axis of the telescope is seen an arm, *n*, extending to the circle, as an index. Now, suppose the index *n* to be at *o*, in the upper part of the circle, when the telescope is horizontal; then if the meridian altitude of the object to be taken is 10°, the index must be moved 10° from *o*, as the degrees on the circle and the altitude of the object will correspond.

* *Plurality of Worlds*, American edition, p. 137.

motion? Where located? Cost? Description by a late writer? Remarks upon its powers? 710. What is a transit instrument? Size? How mounted? Describe parts as shown in the cut. How set the instrument for the meridian altitude of a star?

711. An *Astronomical Clock* is a clock adapted to keep exact sidereal time. Taking the vernal equinox in the heavens as the zero point, and reckoning 24 hours eastward to the same point again, the time—reckoning 15° to an hour—when an object crosses the meridian, will always represent the right ascension of the object. Hence right ascension is usually given in hours, minutes, and seconds; or in time by the astronomical clock, set by the vernal equinox.

THE MURAL CIRCLE.



712. A *Mural Circle* is a large graduated circle, with a telescope crossing its center, used for the measurement of the altitudes and zenith distances of the heavenly bodies, at the instant of their crossing the meridian. They are usually fixed upon a horizontal axis, that turns in a socket firmly fixed in a north and south wall. The degrees, minutes, and seconds on the circle are read by means of microscopes, and indicate the altitude of the object.

In the cut, A is a reading microscope firmly attached to the wall, and B C D E the wall to which the circle is attached. The telescope would denote an altitude of about 40°, which would leave 50° as the zenith distance.

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711. An astronomical clock? How set? How indicate right ascension of objects?
712. Describe a mural circle? Its uses? How mounted? How ascertain altitude and zenith distances by it?

CHAPTER XX.

PROBLEMS AND TABLES.

PROBLEM I.

TO CONVERT DEGREES, ETC., INTO TIME.

Rule I.—Divide the degrees by 15, for hours; and multiply the remainder, if any, by 4, for minutes.

2. Divide the odd minutes and seconds in the same manner by 15 for minutes, seconds, &c., and multiply each remainder by 4, for the next lower denomination.

Example 1.—Convert 32° 34′ 45″ into time.

Thus,	32° ÷ 15 =	2h.	8′	
	34 ÷ 15 =		2	16″
	45 ÷ 15 =			3
Ans.	32° 34′ 45″ =	2h.	10′	19″

Example 2.—If it is 12 o'clock at this place, what is the time 20° east of us?

Thus fifteen in 20°, once, and five over; the *once* is 1 hour, and the 5 multiplied by 4, gives 20 minutes; the time is then 1 hour and 20 minutes past 12.

Example 3.—The longtitude of Hartford is 72° 50′ west of Greenwich; what time is it at Greenwich when it is 12 o'clock at Hartford? Ans. 4h. 51m. 20s.

Example 4.—When it is 12 o'clock at Greenwich, what is the time at Hartford? Ans. 7h. 8m. 40s.

PROBLEM II.

TO CONVERT TIME INTO DEGREES, ETC.

RULE.—Multiply the hours by 15, and to the product add one-fourth of the minutes, seconds, &c., observing that every minute of *time* makes $\frac{1}{4}°$, and every second of time $\frac{1}{4}'$.

EXAMPLE 1.—In 2 hours, 10 minutes, and 19 seconds; how many degrees?

Thus;	2h.	10m.	19.
	15		
	30°		
Add 10 quarters, or $\frac{1}{4}$ of the min.	2	30′	
Add 19 quarters, or $\frac{1}{4}$ of the sec.		4	45″
Ans.	32°	34′	45″

Ex. 2.—When it is 12 o'clock at Hartford, it is 4 hours, 51 minutes, and 20 seconds past noon at Greenwich; how many degrees is Hartford west of Greenwich?

Thus: 15 times 4 is 60—added to $\frac{1}{4}$ of 51, is 72° 45″, and this increased by $\frac{1}{4}$ of 20, is 72° 50′. Ans.

Ex. 3.—A Liverpool packet, after sailing several days from New York, finds the time by the Sun 2 hours and 40 minutes later than by the ship's chronometer: how far has the ship progressed on her way?

Ex. 4.—A vessel leaves Boston, and having been tossed about in foul weather for some days, finds, that when it is 12 o'clock by the Sun, it is only 11 o'clock and 50 minutes by the watch; is the vessel east or west of Boston; and how many degrees?

Ex. 5.—The moment of greatest darkness, during the annular eclipse of 1831, took place at New Haven, 10 minutes after 1 o'clock. A gentleman reports that it happened precisely at 1, where he observed it; and another that it was 5 minutes after 1 where he saw it; *Query.* How far east or west were these gentlemen from each other, and how many degrees from New Haven?

PROBLEM III.

TO FIND WHAT STARS ARE ON THE MERIDIAN AT NINE O'CLOCK IN THE EVENING OF ANY GIVEN DAY.

Rule.—Look for the given day of the month, at the bottom of the maps, and all the stars having the same degree of right ascension will be on the meridian at that time.

Example 1.—What stars will be on the meridian at 9 o'clock, the 19th of January?

Solution.—On Map III. I find that the principal stars standing over against the 19th of January, are Rigel and Capella.

Ex. 2.—What stars are on the meridian the 20th of December? Ans. Menkar and Algol.

PROBLEM IV.

ANY STAR BEING GIVEN, TO FIND WHEN IT CULMINATES.

Rule.—Find the star's right ascension in the table, or by the map (on the equinoctial), and the day of the month at the top or bottom of the map will be the day on which it culminates at 9 o'clock.

Example 1.—At what time is the bright star Sirius on the meridian?

Solution.—I find by the table, and by the map, that the right ascension of Sirius is 6 hours and about 38 minutes; and the time corresponding to this, at the bottom of the map is the 11th of February.

Ex. 2.—At what time is Alpheratz, in the head of Andromeda, on the meridian? Ans. The 9th of November.

PROBLEM V.

THE RIGHT ASCENSION AND DECLINATION OF A PLANET BEING GIVEN, TO FIND ITS PLACE ON THE MAP.

Rule.—Find the right ascension and declination of the planet on the map, and that will be its place for the given day.

Example 1.—Venus's right ascension on the 1st of January, 1833, was 21 hours, 30 minutes, and her declination 16¾° south; required her situation on the map?

Solution.—On the right hand of the Plate II. I count off 16¾° from the equinoctial, on the marginal scale south, and from that point, 30 minutes to the left or just half the distance between the XXI. and XXII. meridian of right ascension, and find that Venus, that day, is within two degrees of Delta Capricorni, near the constellation Aquarius, in the zodiac.

Ex. 2.—Mars' right ascension on the 13th of March, 1833, is 5 hours, 1 minute, and his declination 24¾° north; required his situation on the map?

Solution.—I find the fifth hour line or meridian of right ascension on Plate III.., and counting upward from the equinoctial 24¾°, I find that Mars is between the horns of Taurus, and about 5° S. W. of Beta Aurigæ.

Ex. 3.—Required the position of Jupiter and Saturn on the 13th of February and the 25th of May?

PROBLEM VI.

TO FIND AT WHAT MOMENT ANY STAR WILL PASS THE MERIDIAN ON A GIVEN DAY.

Rule.—Subtract the right ascension of the Sun from the star's right ascension, found in the tables: observing to add 24 hours to the star's right ascension, if less than the Sun's, and the difference will show how many hours the star culminates after the Sun.

Example 1.—At what time will Procyon pass the meridian on the 24th of February?

Solution.—R. A. of Procyon, 7h. 30m. 33s. + 24h.

	31	30′	33″
R. A. of Sun, 24th Feb.	22	29	1
Ans.	9	1	32

That is 1m. 32s. past 9 o'clock in the evening.

Ex. 2.—At what time will Denebola pass the meridian on the first of April?

Solution.—R. A. of Denebola is	11h.	40′	32″
R. A. of Sun, April 1,	0	41	25
Ans.	10	59	7

That is, at 59 minutes, 7 seconds, past 10 in the evening.

Ex. 3.—At what time on the first day of each month, from January to July, will Alcyone, or the Pleiades, pass the meridian?

Ex. 4.—At what time will the Dog-Star, or Sirius, culminate on the first day of January, February, and March?

Ex. 5.—How much earlier will Spica Virginis pass the meridian on the 4th of July, than on the 15th of May?

Ans. 3 hours, 25 minutes.

PROBLEM VII.

TO FIND THE SUN'S LONGITUDE OR PLACE IN THE ECLIPTIC, ON ANY GIVEN DAY.

Rule.—On the lower scale, at the bottom of the Planisphere (Map VIII.) look for the given day of the month; then the sign and degree corresponding to it on the scale immediately above it will show the Sun's place in the ecliptic.

Example 1.—Required the Sun's longitude, or place in the ecliptic, the 16th of September.

Solution.—Over the given day of the month, September 16th, stands 5 signs and 23 degrees, nearly, which is the Sun's place in the ecliptic at noon on that day; that is, the Sun is about 23 degrees in the sign Virgo.

N.B.—If the 5 signs be multiplied by 30, and the 23 degrees be added to it, it will give the longitude in degrees, 173.

Ex. 2.—Required the Sun's place in the ecliptic at noon, on the 10th of March.

PROBLEM VIII.

GIVEN THE SUN'S LONGITUDE, OR PLACE IN THE ECLIPTIC, TO FIND HIS RIGHT ASCENSION AND DECLINATION.

Rule.—Find the Sun's place in the ecliptic (the curved line which runs through the body of the planisphere), and with a pair of compasses take the nearest distance between it and the nearest meridian, or hour circle, which being applied to the graduated scales at the top or bottom of the planisphere (measuring from the same hour circle), will show the Sun's right ascension. Then take the shortest distance between the Sun's place in the ecliptic and the nearest part of the equinoctial, and apply it to either the east or west marginal scales, and it will give the Sun's declination.

Example 1.—The Sun's longitude, September 16th, 1833, is 5 signs, 23 degrees, nearly; required his right ascension, and declination.

Solution.—The distance between the Sun's place in the ecliptic and the nearest hour circle being taken in the compasses, and applied to either the top or bottom graduated scales, shows the right ascension to be about 11 hours 35 minutes; and the distance between the Sun's place in the ecliptic, and the nearest part of the equinoctial, being applied to either the east or west marginal scales, shows the declination to be about 2° 45′, which is to be called north, because the Sun is to the northward of the equinoctial; hence the Sun's right ascension, on the given day, at noon, is about 11 hours 35 minutes, and his declination 2° 45′ N.

Ex. 2.—The Sun's longitude, March 10th, 1833, is 11 signs, 19 degrees, nearly; required his right ascension and declination?

Ans. R. A. 23h. 21m. Decl. 4° 11′ nearly.

PROBLEM IX.

TO FIND THE RIGHT ASCENSION OF THE MERIDIAN AT ANY GIVEN TIME.

Rule.—Find the Sun's place in the ecliptic by Problem IX., and his right ascension by Problem X., to the eastward of which count off the given time from noon, and it will show the right ascension of the meridian, or mid-heaven.

Example 1.—Required the right ascension of the meridian 9 hours, 25 minutes past noon, September 16th, 1833?

Solution.—By Problems IX. and X., the Sun's right ascension at noon of the given day, is 11 hours 35 minutes; to the eastward of which, 9 hours and 25 minutes (the given time) being counted off, shows the right ascension of the meridian to be about 21 hours.

Ex. 2.—Required the right ascension of the meridian at 6 hours past noon, March 10th, 1833?

Solution.—By Problems IX. and X., the Sun's right ascension at noon of the given day, is 23 hours and 21 minutes; to the eastward of which, the given time, 6 hours, being counted off, shows the right ascension of the meridian to be about 5 hours, 21 minutes.

Remark.—In this example, it may be necessary to observe, that where the eastern, or left-hand extremity of the planisphere leaves off, the western, or right-hand extremity begins; therefore, in counting off the given time on the top or bottom graduated scales, the reckoning is to be transferred from the left, and completed on the right, as if the two outside edges of the planisphere were joined together.

PROBLEM X.

TO FIND WHAT STARS WILL BE ON OR NEAR THE MERIDIAN, AT ANY GIVEN TIME.

Rule.—Find the right ascension of the meridian by Problem XI., over which lay a ruler, and draw a pencil line along its edge from the top to the bottom of the planisphere, and it will show all the stars that are on or near the meridian.

Example 1.—Required what stars will be on or near the meridian at 9 hours, 25 minutes past noon, Sept. 16th, 1833?

Solution.—The right ascension of the meridian by Problem XI. is 21 hours: this hour circle, or the line which passes up and down through the planisphere, shows that no star will be directly on the meridian at the given time; but that Alderamin will be a little to the east, and Deneb Cygni a little to the west of it; also Zeta Cygni, and Gamma and Alpha in the Little Horse, very near it on the east.

PROBLEM XI.

TO FIND THE EARTH'S MEAN DISTANCE FROM THE SUN.

Rule.—As the Sun's horizontal parallax is to radius, so is the semi-diameter of the Earth to its distance from the Sun.

By Logarithms.—As tangent of the Sun's horizontal parallax is to radius, so is the Earth's semi-diameter to her mean distance from the Sun.

8".5776 : 206264".8 : : 3962 : 95,273,869 miles.

By Logarithms.

As tangent of the Sun's horizontal parallax, 8".5776=	5.6189407
Is to radius, or 90°,	=10·0000000
So is the Earth's semi-diameter, 3962=	3.5979143
To the Earth's distance, 95,273,869=	7.9789738

PROBLEM XII.

TO FIND THE DISTANCE OF ANY PLANET FROM THE SUN, THAT OF THE EARTH BEING KNOWN.

Rule.—Divide the square of the planet's sidereal revolution round the Sun, by the square of the Earth's sidereal revolution, and multiply the cube root of the quotient by the Earth's mean distance from the Sun.

By Logarithms.—From twice the logarithm of the planet's sidereal revolution, subtract twice the logarithm of the Earth's sidereal revolution, and to one-third of the remainder, add the logarithm of the Earth's mean distance from the Sun.

Example.—Required Mercury's mean distance from the Sun, that of the Earth being 95,273,869 miles.

Mercury's sidereal revolution is 87.969258 days, or 7600543".8912 : the Earth's sidereal revolution is 365.256374417 days, or

31558151".5	7600543.9
31558151".5	7600543.9

995916962096952.25 by which divide 57768267575827.21 and the quotient will be 0.052005106713292, the cube root of which is 0.3870977, and this multiplied by 94,881,891, gives 36,727,607 miles, for Mercury's distance from the Sun. This problem may be performed by logarithms in as many *minutes* as the former method requires *hours*.

Mercury's Sid. Rev. 7600543".9 log.=6.8808447 × 2	13.7616894
Earth's Sid. Rev. 31558151". log.=7.4991302 × 2	14.9982604
	⅓)—2.7634290
	1.5878097
Add log. of the Earth's mean distance,	7.9789738
Mercury's distance, 36,880,422. Ans.	7.5667835

If the pupil have not already learned the use of logarithms, this problem will satisfy him of their unspeakable advantage over all other modes of computation. By reviewing the above calculation, he will perceive that instead of multyplying 31558151'.5 by itself, he need only multiply its logarithms by *two!* and instead of extracting the cube root of 0.058005106713292, he need only divide its logarithm by *three!* and instead of multiplying 0.3870977, by 95,273,869, he need only *add* their logarithms together. He need not think himself a *dull* scholar, if by the former method he come to the true result in *five hours;* nor remarkably quick, if by the latter he come to it in *five minutes.*

PROBLEM XIII.

TO FIND THE HOURLY MOTION OF A PLANET IN ITS ORBIT.

Rule.—Multiply the planet's mean distance from the Sun by

6.2831853, and divide the product by the time of the planet's sidereal revolution, expressed in hours, and the decimals of an hour.

By Logarithms.—Add 0.7981799 to the logarithm of the planet's mean distance from the Sun, and from the sum subtract the logarithm of the planet's revolution expressed in hours.

EXAMPLE.—Required the Earth's hourly motion in its orbit.

Log. of Earth's distance=7.9780738+0.7981799=	8.7771537
Subtract log. of Earth's revolution	3.9428090
Gives Earth's horary motion, 68,288 miles,	4.8343447

PROBLEM XIV.

TO FIND THE HOURLY MOTION OF A PLANET ON ITS AXIS.

RULE.—Multiply the diameter of the given planet by 3.14159, and divide the product by the period of its diurnal rotation.

By Logarithms.—Add 4.0534524 to the logarithm of the planet's diameter, and from the sum subtract the logarithm of its diurnal rotation, expressed in seconds.

Earth's diameter, 7924 log. =	3.8989445
Add log. of 3600″+log. of 3.14159 =	4.0534524
	7.9523969
Subtract log. diurnal rotation, 23h. 56′ 4″.09 =	4.9353263
Ans. 1040.09 miles =	3.0170706

PROBLEM XV.

TO FIND THE RELATIVE MAGNITUDE OF THE PLANETS.

RULE.—Divide the cube of the diameter of the larger planet by the cube of the diameter of the less.

By Logarithms.—From three times the logarithm of the larger, subtract three times the logarithm of the less.

EXAMPLE.—How much does the size of the Earth exceed that of the Moon?

Earth's diameter, 7912 log. 3.8982863 × 3=	11.6948589
Moon's diameter, 2160 log. 3.3343376 × 3=	10.0030128
The Earth exceeds the Moon, 49.1865 times. Ans.	1.6918461

In this example, 7912 miles is assumed as the *mean* between the Earth's equatorial and polar diameter: the former being 7924, and the latter 7898 miles.

PROBLEM XVI.

TO FIND THE PROPORTION OF SOLAR LIGHT AND HEAT AT EACH OF THE PLANETS.

RULE.—Divide the square of the planet's greater distance from the Sun, by the square of the less.—Or, subtract twice the logarithm of the greater distance from twice the logarithm of the less.

EXAMPLE.—How much greater is the Sun's light and heat at Mercury, than at the Earth?

Log. of Earth's distance	7.9789738 × 2 = 15.9579476
" of Mercury's	7.5667959 × 2 = 15.1335918
Ans. 6.6736 times greater =	0.8243558

PROBLEM XVII.

TO FIND THE CIRCUMFERENCE OF THE PLANETS.

RULE.—Multiply the diameter of the planet by 3.14159, or, add the logarithm of the planet's diameter to 0.4971499.

PROBLEM XVIII.

TO FIND THE CIRCUMFERENCE OF THE PLANETARY ORBITS.

RULE.—Multiply the planet's mean distance from the Sun by 6.2831853; or, to the logarithm of the planet's mean distance, add 0.7981799, and the sum will be the logarithm of the answer.

PROBLEM XIX.

TO FIND IN WHAT TIME ANY OF THE PLANETS WOULD FALL TO THE SUN, IF LEFT TO THE FORCE OF GRAVITATION ALONE.

RULE.—Multiply the time of the planet's sidereal revolution by 0.176776; the result will be the answer.

By Logarithms.—From the logarithm of the planet's sidereal revolution, subtract 0.7525750, and the remainder will be the logarithm of the answer, in the same denomination as the sidereal revolution.

Required the times, respectively, in which the several planets would fall to the Sun by the force of gravity.

Planets would fall to the Sun.	Days.	H.	M.	S.	Logarithms.
Mercury,	15	13	13	16	6.1282686
Venus,	39	17	19	22	6.5355424
Earth,	64	13	38	55	6.7465357
Mars,	121	10	36	3	7.0208817
Jupiter,	265	21	33	35	7.8206849
Saturn,	1901	23	24	4	8.2157186
Herschel,	5424	16	52	1	8.6708897
Moon to the Earth,	4	19	54	57	5.6204459

THE END.

EXPLANATIONS AND PROBLEMS

ADAPTED TO

WHITALL'S PLANISPHERE.

NOTE.—This is a movable Planisphere, invented and copyrighted by Henry Whitall, and for sale by the publishers of Burritt's Geography of the Heavens, exhibiting the stars that are rising, setting, on the meridian, or their position in the firmament, as seen in the United States every five minutes for HUNDREDS OF YEARS. The right ascension and declination of the sun, moon, stars, and planets; the equation of time (sun fast or slow); harvest moon; sun and moon running high and low; the milky way, as it changes its course for every hour; change of seasons, etc., can be readily explained with this invaluable substitute for a Celestial Globe, "being as much better as it is cheaper" than that expensive school apparatus.

It is light, portable, accurate, containing much within a small space, and is sold for TWO DOLLARS AND A HALF, which price brings it within the means of all lovers of science, and of every teacher who may desire his pupils to become acquainted with the wonders of the heavens. This knowledge need no longer be confined to the learned few, for the use of this Planisphere will enable any one to become familiar with the stars and constellations, and will prove both pleasing and instructive. The desideratum so long desired is thus supplied, and reading the stars is no longer a mystery.

PROBLEMS

WHICH MAY BE PERFORMED ON THE PLANISPHERE.

THE DAY OF THE MONTH, THE HOUR AND MINUTE BEING GIVEN, TO FIND WHAT STARS ARE RISING, SETTING, ON THE MERIDIAN, OR IN ANY PART OF THE FIRMAMENT.

Application.—Bring the given day of the month to 12 noon, turn the index to the given hour and minute, hold it overhead, with the meridian line, north and south; the Planisphere will then represent in miniature the constellations visible in the heavens at that time. The stars which are rising are near the eastern, and those setting near the western horizon. And thus can be seen the stars in any part of the heavens, at all times, sufficiently accurate for most practical purposes.

Example.—Given this evening at 9 o'clock, or any other time, to find what stars are rising in the east, setting in the west, those in the northern or southern horizon, in the zenith, or in any other part of the firmament.

Example.—Where will An-drom′e-da be on the 10th of November at 10 o'clock? (29.) Ans. Directly over head.

Example.—Where will the Pleiades be 10 minutes before 9 o'clock on the evening of the 1st of January? (66.) Ans. On the meridian.

Example.—What remarkable cluster of stars rise between the N.E. and N.E. by E. points of the horizon, at half past 8 o'clock, P. M., on the 6th of September? Ans. Ple′ia-des, or seven stars.

Example.—What bright star will set near the N.W. by W. about 5 minutes before 11 o'clock on the 6th of September? Ans. Arc-tu′rus.

Example.—What star will rise in the E.S.E. at 8 o'clock on the 20th of December? And what star will set about 15 minutes later in the W. by N.? Ans. Sir′i-us, the brightest fixed star, and Altair.

Example.—What stars will be on and near the meridian about 8 o'clock on the 21st of November? Ans. Caph. in Cas-si-o-pe′ia, Alpheratz in Androm′e-da, and Al′gen-ib in Peg′a-sus, marking out the first meridian.

TELESCOPIC OBJECTS.

The right ascension of the telescopic objects are given in hours and minutes. To find their place in the heavens, bring the 21st of March to 12 noon; turn the index to the hour and minute of R. A.; opposite the declination, marked on the meridian, will be the situation of the object; on the equator opposite 0 can be seen the degrees of R. A.

Should the R. A. be 13 hours, bring the index to 1 past midnight; for 14 hours bring it to 2.

α Virginis (Spica) R. A. 13 hours, 16 minutes, 47 seconds, turn the index to 1 hour, 16 minutes past midnight, and its place is 10° 19′ 5″ south of the equator.

α Bo-o′tis (Arcturus) R. A. 14 hours, 8 minutes, 23 seconds, turn the index to 2 hours, 8 minutes, 22 seconds past midnight, its place will be under the 20° mark on the meridian, north of the equator.

α Scorpii (Antares) R. A. 16 hours, 19 minutes, 36 seconds, turn the index to 4 hours, 19 minutes, 36 seconds past midnight, and its place is 26° 04′ 3″ south its declination.

THE RIGHT ASCENSION AND DECLINATION OF THE SUN, MOON, PLANET, STAR, OF COMET, BEING GIVEN, TO FIND ITS PLACE ON THE PLANISPHERE.

Bring the graduated side of the meridian to the degrees of right ascension marked on the equator.

Its place will be under the declination marked on the meridian.

EXAMPLE.—Given the right ascension of a star 212°, declination 20° north. To find its place on the Planisphere. (169.) Ans. Arc-tu′rus.

EXAMPLE.—What star has its R. A. 342°, D. 30½° south? Ans. Fo′malhaut.

TO FIND THE RIGHT ASCENSION AND DECLINATION OF THE SUN FOR EVERY DAY OF THE YEAR.

The sun's place among the stars, is on the ecliptic where the day of the month is. Bring the meridian to the day required. The declination will be found opposite on the meridian, and the right ascension opposite 0, on the equator.

Or, bring the day of the month to 12 noon, turn the index there also; 0 on the meridian meets the equator, where will be found the degrees of right ascension. The day of the month (the sun's place among the stars), will be where the meridian meets the ecliptic, and the declination opposite on the meridian.

EXAMPLE.—What is the right ascension and declination of the sun on the 21st of March? Ans. 0.

EXAMPLE.—What is the right ascension and declination of the sun on the 22d of June? Ans. 90° R. A., 23½° N. D.

What is the right ascension and declination of the sun on the 22d of December? Ans. 270° R. A., 23½° S. D.

TO FIND ON WHAT DAY OF THE YEAR ANY STAR PASSES THE MERIDIAN AT A GIVEN HOUR OR MINUTE.

Bring the meridian to the centre of the star, by the ribbons turn the Planisphere until the index meets the given time. Opposite 12, noon, will be found the day required.

EXAMPLE.—When will Reg′-u-lus be on the meridian at 9 o'clock, evening? (124.) Ans. 5th of April. When will Altair be on the meridian at 9½ o'clock, evening? Ans. 25th of August.

When will Arcturus be on the meridian at 9 o'clock? (169.) Ans. 9th of June.

When will *a* Spica Virginis be on the meridian at 9 o'clock in the evening? (162.) Ans. About the 28th of May.

THE DAY OF THE MONTH BEING GIVEN, TO FIND AT WHAT TIME ANY STAR WILL COME TO THE MERIDIAN.

Bring the day of the month to 12 noon. Turn the graduated side of the meridian to the centre of the star. The index will point out the time required.

EXAMPLE.—At what time will *a* Vega come to the meridian, on the 25th of August? Ans. 8 o'clock, 15 minutes.

At what hour will An-ta′res, in Scorpio, come to the meridian on the 10th of July? (199.) Ans. 9 o'clock.

TO CONVERT TIME INTO DEGREES, OR DEGREES INTO TIME.

Bring the 21st of March to 12 noon. Turn the index to the same point. The movable meridian and first meridian coincide, from which the right ascension of all the heavenly bodies is measured east on the equator, counting 10, 20 to 360 degrees, to the vernal equinox or place of beginning.

The index will point to the hour and minute of right ascension reading 12, 13 to 24 hours. One degree on the equator being equal to 4 minutes pointed out by the index, fifteen degrees equal to one hour, so on the equator can be read degrees, and the index shows the hours and minutes of right ascension.

EXAMPLE.—100° on equator equal 6 hours 40 minutes, shown by index. 212° equal 14 hours, 8 minutes. 276½° equal 18 hours, 26 minutes.

The sun fast or slow depends upon two causes, viz.: the obliquity of the ecliptic and the unequal motion of the earth in its orbit. The Planisphere will indicate the equation of time dependent upon the former. Bring the graduated side of the meridian to 30° on the equator (mean clock time), note the time shown by the index. Then bring the meridian to 30° on the ecliptic (sun's or apparent time), the sun is as many minutes fast, as it is west of mean clock time shown by the index. Again, bring the meridian to 150° on the equator, the sun is then as many minutes slow as 30° (the fifth sign on the ecliptic) is east of mean time shown by the index. (397.)

The Seasons—different length of days and nights.—An illustration of (616), bring the 20th of March to 12 noon, turn the index to 6, morning, the 20th day of March (or sun's place on the ecliptic), will be near the eastern horizon; turn the index to 6, evening, the sun's place will be found setting near the west, thus showing the days and nights to be equal.

Bring the 21st of June to 12 noon, find that day on the ecliptic, turn the index until the day found meets the north-eastern horizon, and the index will show about the time the sun rises; turn the index until the north-western horizon meets the same day, when the index will show near the time of the sun setting, thus showing the days to be about four hours longer than they are on the 20th of March, and the nights that time shorter.

(617.) Bring the 21st of December to 12 noon, find the day on the ecliptic, and turn the index until the south-eastern horizon meets the day, the index will point nearly to the time of the sun's rising; turn the index until the south-western horizon meets the same day for the approximate time of setting, thus showing the days to be about four hours shorter than they are on the 23d of September, and the nights that much longer.

The Harvest Moon (626—635) (so called in some parts of Europe) is of great benefit to the husbandman by lengthening the day while gathering the fruits of the earth, and takes place at the full moon in September, when the moon rises for several evenings near the same hour. Shown on the Planisphere by bringing the 15th day of September to 12 noon, and turning the index to 6½ o'clock evening. The eastern horizon, first meridian, ecliptic, and equator, meet at the vernal equinox. Should the moon full on that day, and rise with the vernal equinox at 6½ o'clock; on the following evening, she will have gained about 12° on the sun, then turn the index until 12° on the ecliptic rises, note the time shown by the index, bring 12° more up again, note the time. Thus it can be seen that when the ecliptic is nearest parallel to the horizon, the difference of time in the moon's rising is least, and setting greatest; when the ecliptic is nearest perpendicular to the horizon, then will be the greatest difference of time in her rising, and the least in setting.

IN SUMMER, WHEN THE SUN RUNS HIGHEST, THE FULL MOON RUNS LOWEST. IN WINTER, WHEN THE SUN RUNS LOWEST, THE FULL MOON RUNS HIGHEST. (421.)

Bring the 22d of June to 12 noon. Turn the index to the same point; where the meridian meets the ecliptic will be found the day of the month (sun's place among the stars), at his greatest distance north, shown by the degrees marked on the meridian. Should the moon full on that day, she will be found in the opposite part of the firmament, shown by bringing the index to 12 midnight, to be within 5° of where the meridian meets the ecliptic, at her greatest distance south. Turn the index to about 8 o'clock evening. The sun's place of setting will be shown near N.W. by W., and moon's place of rising near S.E. by E.

In winter bring 22d of December to 12 noon, turn the index there also, where the meridian meets the ecliptic will be the sun's place at his greatest distance south. Should the moon full on that day, she will be in the opposite part of the heavens. Shown by bringing the index to 12 midnight, to be near the ecliptic at her greatest distance north. Turn the index to 4 o'clock afternoon, the sun will be found to set near S.W. by W., and full moon to rise near N.E. by E.

GIVEN THE DAY AND HOUR, TO TELL THE COURSE AND POSITION OF THE MILKY WAY.

Bring the day of the month to 12 noon, turn the index to the given time, the course and position can be readily traced on the Planisphere. (256—260.)

EXAMPLE.—What will be the course of the milky way on the 5th of September at 6, 9, 12, and 5 o'clock? Ans. At 6 o'clock evening, starting from northern horizon, to east of zenith, to southern horizon. At 9 o'clock it appears in the N.E., in zenith, to S.W. At 12 midnight it appears in E.N.E., passes meridian at 60° north, to the W.S.W. At 5 o'clock, morning, it appears in the S.E., passes the zenith, to the N.W.

GIVEN THE TIME OF THE MOON OR PLANET'S SOUTHING, TO FIND ITS PLACE AMONG THE STARS.

Bring the day of the month, to 12 noon. Turn the index to the hour and minute, the moon or planet souths, or comes to the meridian, its place will be near where the graduated side of the meridian meets the ecliptic.

To find when it will rise, turn the index until the eastern horizon meets the place found on the Planisphere; the index points out the time. Bring the western horizon there for the time of setting.